# Sepam$^{\text{TM}}$ Series 80
# Protective Relays
## Reference Manual

Instruction Bulletin

63230-216-230B1

Main No. 2
G
Ia= 175 A
Vab= 6.61 kV
P= 1.81 MW
Q= 860 kVAR
on
Trip
I on
O off
ext
Io>>51N
Io>51N
I>>51
I>51
Remote
Local
Test
clear
reset

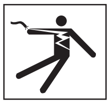
Merlin Gerin
Square D
Telemecanique

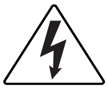
Schneider Electric

# Safety Instructions

## Safety Symbols and Messages

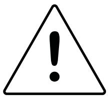
Read these instructions carefully and look at the equipment to become familiar with the device before trying to install, operate, service or maintain it. The following special messages may appear throughout this bulletin or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.


ANSI symbol


IEC symbol

### Risk of Electric Shock

The addition of either symbol to a “Danger” or “Warning” safety label on a device indicates that an electrical hazard exists, which will result in death or personal injury if the instructions are not followed.



### Safety Alert

This is the safety alert symbol. It is used to alert you to potential personal injury hazards and prompt you to consult the manual. Obey all safety instructions that follow this symbol in the manual to avoid possible injury or death.

### Safety Messages

| ⚠ DANGER |
|---|
| DANGER indicates an imminently hazardous situation which, if not avoided, will result in death, serious injury or property damage. |

| ⚠ WARNING |
|---|
| WARNING indicates a potentially hazardous situation which, if not avoided, **could result in** death, serious injury or property damage. |

| ⚠ CAUTION |
|---|
| CAUTION indicates a potentially hazardous situation which, if not avoided, minor or moderate injury or property damage. |

## Important Notes

### Restricted Liability

Electrical equipment should be serviced and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this manual. This document is not intended as an instruction manual for untrained persons.

### Device Operation

The user is responsible for checking that the rated characteristics of the device are suitable for its application. The user is responsible for reading and following the device’s operating and installation instructions before attempting to commission or maintain it. Failure to follow these instructions can affect device operation and constitute a hazard for people and property.

### Protective Grounding

The user is responsible for compliance with all the existing international and national electrical codes concerning protective grounding of any device.

### FCC Notice

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense. This Class A digital apparatus complies with Canadian ICES-003.

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# Sepam™ Protective Relays
Overview

*The Sepam™ range of protection relays is designed for all protection applications on medium-voltage public and industrial distribution networks.*

*It consists of three series of relays, with increasing levels of performance:*

- *Sepam™ Series 20, for simple applications*
- *Sepam™ Series 40, for demanding applications*
- *Sepam™ Series 80, for custom applications*

*All information relating to the Sepam™ range can be found in the following documents:*

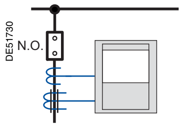
- *Sepam™ Family Catalog, reference 63230-216-238*
- *Sepam™ Series 20 User's Manual, reference 63230-216-208*
- *Sepam™ Series 40 User's Manual, reference 63230-216-219*
- *Sepam™ Series 80 Reference Manual, reference 63230-216-230*
- *Sepam™ Series 80 Modbus Communication User's Manual, reference 63230-216-231*
- *Sepam™ Series 80 Operation Manual, reference 63230-216-229*
- *Sepam™ DNP3 Communication User's Manual, reference 63230-216-236*
- *Sepam™ IEC 60870-5-103 Communication User's Manual, reference 63230-216-237*

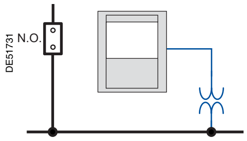
## Sepam™ Series 20

### For Simple Applications

**Characteristics**

- 10 logic inputs
- 8 relay outputs
- 1 communication port
- 8 temperature sensor inputs



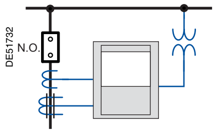


## Sepam™ Series 40

### For Demanding Applications

**Characteristics**

- 10 logic inputs
- 8 relay outputs
- Logic equation editor
- 1 communication port
- 16 temperature sensor inputs

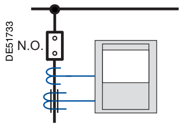


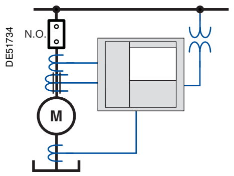
## Sepam™ Series 80

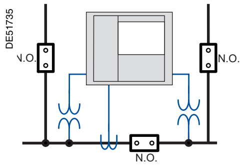
### For Custom Applications

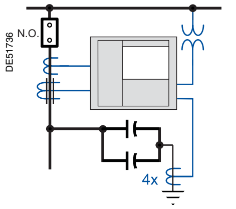
**Characteristics**

- 42 logic inputs
- 23 relay outputs
- Logic equation editor
- 2 communication ports for multimaster or redundant architecture
- 16 temperature sensor inputs
- Removable memory cartridge with parameters and settings for quick return to service after replacement
- Battery for storing logs and recording data
- Mimic-based User Machine Interface for local control of the device in complete safety
- Optional Logipam programming software, for programming dedicated functions









# Sepam™ Protective Relays
## Overview

| Protection | | Applications | | | | | |
|---|---|---|---|---|---|---|---|
| Standard | Specific | Substation | Bus | Transformer | Motor | Generator | Capacitor |
| Current protection | Breaker failure | **S23** | | **T23** | **M20** | | |
| Voltage and frequency protection | | | **B21** | | | | |
| | Disconnection (ROCOF) | | **B22** | | | | |
| Current, voltage, and frequency protection | | **S40** | | **T40** | | **G40** | |
| | Directional ground fault | **S41** | | | **M41** | | |
| | Directional ground fault and phase overcurrent | **S42** | | **T42** | | | |
| Current, voltage and frequency protection | | **S80** | **B80** | | | | |
| | Directional ground fault | **S81** | | **T81** | **M81** | | |
| | Directional ground fault and phase overcurrent | **S82** | | **T82** | | **G82** | |
| | Disconnection (ROCOF) | **S84** | | | | | |
| Current, voltage, and frequency protection | Transformer or machine-transformer unit differential | | | **T87** | **M88** | **G88** | |
| | Machine differential | | | | **M87** | **G87** | |
| Current, voltage, and frequency protection | Voltage and frequency protection for two sets of busses | | **B83** | | | | |
| Current, voltage, and frequency protection | Capacitor bank unbalance | | | | | | **C86** |

*The Sepam™ range of protection relays is designed for operating machines, the electrical distribution networks of industrial installations, and utility substations at all levels of voltage. The Sepam™ family includes:*

- *Sepam™ Series 20*
- *Sepam™ Series 40*
- *Sepam™ Series 80*

*to cover all needs, from the simplest to the most complete.*

PE50278
I1 = 165A RMS
I2 = 166A RMS
I3 = 167A RMS

*Sepam™ Series 80 with integrated advanced UMI*

## Sepam™ Series 80: Intelligent Solutions for Custom Applications

Specially designed for demanding customers on large industrial sites, Sepam™ Series 80 provides proven solutions for electrical distribution and machine protection

## Main Characteristics

**The Sepam™ Series 80 offers these features:**

- protects closed ring networks or networks with parallel mains by means of directional protection and zone selective interlocking
- directional ground fault protection for impedance-grounded and effectively ungrounded or compensated neutral systems (designed to compensate for system capacitance using a tuned inductor in the neutral. This is not common in North America).
- complete protection of transformers and machine-transformer units
  - stable, sensitive differential protection with neural network restraint
  - linked to all necessary backup protection functions
- complete protection of motors and generators
  - against internal faults:
    - stable, sensitive machine differential protection, with starting and instrument transformer loss restraint
    - field loss, stator ground fault
  - against network and process faults: pole slip, speed control, inadvertent energization
- sync-check between two networks before closing tie breaker
- measurement of harmonic distortion, current and voltage, to assess network power quality
- 42 inputs / 23 outputs for comprehensive equipment control
- mimic-based UMI for local switchgear control
- SFT2841 parameter setting and operating software, a simple and complete tool that is indispensable for all Sepam™ users:
  - assisted preparation of parameter and protection settings
  - complete information during commissioning
  - remote equipment management and diagnostics during operation
- logic equation editor built into the SFT2841 software to adapt the predefined control functions
- optional SFT2885 programming software (Logipam), to program specific control and monitoring functions
- two communication ports to integrate Sepam™ in two different networks or redundant architectures
- removable memory cartridge to get equipment in operation again quickly after the replacement of a faulty base unit
- battery backup to save historical and disturbance recording data

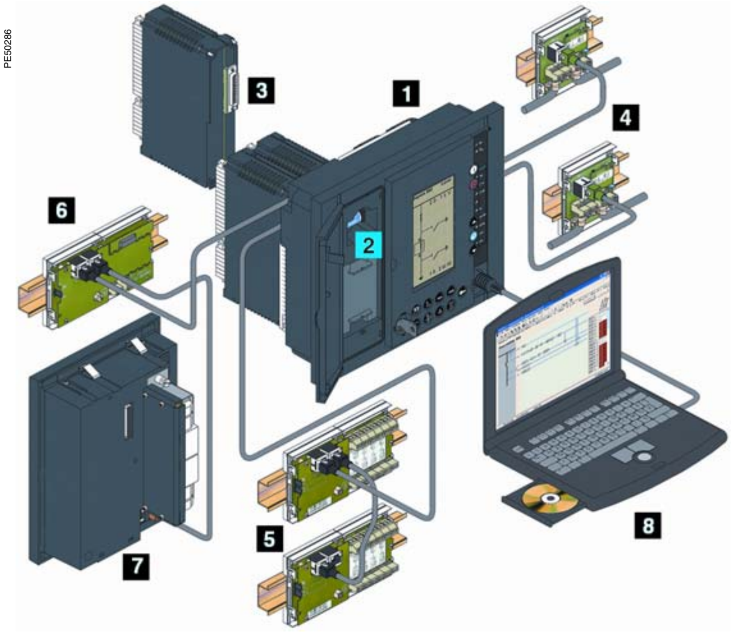
## Selection Guide

**The Sepam™ Series 80 family** includes 16 types to offer the right solution for each application.

| Specific Protection Functions Available | Applications | | | | | |
|---|---|---|---|---|---|---|
| **General Performance** | **Substation** | **Transformer** | **Motor** | **Generator** | **Bus** | **Capacitor** |
| Non-directional phase and ground faults | S80 | | | | B80 | |
| Directional ground fault | S81 | T81 | M81 | | | |
| Directional ground fault and phase overcurrent | S82 | T82 | | G82 | | |
| Check on 3-phase voltages on two busses | | | | | B83 | |
| Rate of change of frequency | S84 | | | | | |
| Capacitor bank unbalance | | | | | | C86 |
| Transformer or machine differential | | T87 | M87 | G87 | | |
| Machine-transformer unit differential | | | M88 | G88 | | |

## Flexibility and Upgrading Capability

The user can add optional modules to Sepam™ at any time for increased functionality. This gives Sepam™ exceptional versatility, adapting to as many situations as possible, and allowing for future installation upgrade,



**1** **Base unit, with different types of User Machine Interfaces (UMI):**
- integrated mimic-based UMI
- integrated or remote advanced UMI

**2** **Parameter and protection settings saved on removable memory cartridge.**

**3** **42 logic inputs and 23 output relays**
with three optional modules providing 14 inputs and 6 outputs.

**4** **Two independent communication ports**
- direct connection to 2-wire RS485, 4-wire RS485 and fiber optic networks
- connection to Ethernet TCP/IP network via PowerLogic Ethernet server (Transparent Ready™)

**5** **Processing of data from 16 temperature sensors,**
Pt100, Ni100 or Ni120.

**6** **1 low level analog output,**
0-10 mA, 4-20 mA or 0-20 mA

**7** **Sync-check module**

**8** **Software tools:**
- Sepam™ parameter and protection setting, and predefined control functions adaptation
- local or remote installation operation
- programming specific functions (Logipam)
- retrieval and display of disturbance recording data

## Easy Installation

- light, compact base unit
- easy to integrate due to Sepam's adaptation capabilities:
  - universal supply voltage and logic inputs: 24 to 250 V DC
  - phase currents may be measured by 1A or 5A current transformers, or LPCT (Low Power Current Transducer) type CTs
  - residual current calculated or measured by a choice of methods to fit requirements
- the same, easy-to-install remote modules for all Sepam™ units:
  - mounted on DIN rail
  - connected to the Sepam™ base unit by prefabricated cords

## Commissioning Assistance

- predefined functions implemented by simple parameter setting
- user-friendly, powerful SFT2841 PC setting software tool used on all Sepam™ units to provide users with all the possibilities offered by Sepam™.

## Intuitive Use

- integrated or remote advanced User Machine Interface (UMI) installed in the most convenient place for the facility manager
- integrated mimic-based User Machine Interface for local control of switchgear
- user-friendly User Machine Interface, with direct access to data
- clear graphic LCD display of all data required for local operation and installation diagnosis
- working language may be customized to be understood by all users

# Selection Table

| | | Substation | | | | Transformer | | | Motor | | | Generator | | | Bus | | Cap. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Protection** | **ANSI Code** | **S80** | **S81** | **S82** | **S84** | **T81** | **T82** | **T87** | **M81** | **M87** | **M88** | **G82** | **G87** | **G88** | **B80** | **B83** | **C86** |
| Phase overcurrent [1] | 50/51 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Ground fault / Sensitive ground fault [1] | 50N/51N<br>50G/51G | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Breaker failure | 50BF | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Negative sequence / unbalance | 46 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Thermal overload for cables | 49RMS | | 2 | 2 | 2 | | | | | | | | | | | | |
| Thermal overload for machines [1] | 49RMS | | | | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | | |
| Thermal overload for capacitors | 49RMS | | | | | | | | | | | | | | | | 2 |
| Capacitor bank unbalance | 51C | | | | | | | | | | | | | | | | 8 |
| Restricted ground fault | 64REF | | | | | 2 | 2 | 2 | | | | 2 | | 2 | | | |
| Two-winding transformer differential | 87T | | | | | | | 1 | | | 1 | | | 1 | | | |
| Machine differential | 87M | | | | | | | | | 1 | | | 1 | | | | |
| Directional phase overcurrent [1] | 67 | | | 2 | 2 | | 2 | 2 | | | | 2 | 2 | 2 | | | |
| Directional ground fault [1] | 67N/67NC | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | | |
| Directional active overpower | 32P | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | | |
| Directional reactive overpower | 32Q | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| Directional active underpower | 37P | | | | 2 | | | | | | | 2 | | | | | |
| Phase undercurrent | 37 | | | | | | | | 1 | 1 | 1 | | | | | | |
| Excessive starting time, locked rotor | 48/51LR | | | | | | | | 1 | 1 | 1 | | | | | | |
| Starts per hour | 66 | | | | | | | | 1 | 1 | 1 | | | | | | |
| Field loss (underimpedance) | 40 | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| Pole slip | 78PS | | | | | | | | 1 | 1 | 1 | 1 | 1 | 1 | | | |
| Overspeed (2 set points) [2] | 12 | | | | | | | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | | |
| Underspeed (2 set points) [2] | 14 | | | | | | | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | | |
| Voltage-restrained overcurrent | 50V/51V | | | | | | | | | | | 2 | 2 | 2 | | | |
| Underimpedance | 21B | | | | | | | | | | | 1 | 1 | 1 | | | |
| Inadvertent energization | 50/27 | | | | | | | | | | | 1 | 1 | 1 | | | |
| Third harmonic undervoltage / 100 % stator ground fault | 27TN/64G2<br>64G | | | | | | | | | | | 2 | 2 | 2 | | | |
| Overexcitation (V / Hz) | 24 | | | | | | | 2 | | | | 2 | 2 | 2 | | | |
| Positive sequence undervoltage | 27D | 2 | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 4 |
| Remnant undervoltage | 27R | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Undervoltage (L-L or L-n) | 27 | 4 | 4 | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 2 | 2 |
| Overvoltage (L-L or L-n) | 59 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Neutral voltage displacement | 59N | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Negative sequence overvoltage | 47 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Overfrequency | 81H | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Underfrequency | 81L | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Rate of change of frequency | 81R | | | | 2 | | | | | | | | | | | | |
| Recloser (4 shots) [2] | 79 | ☐ | ☐ | ☐ | ☐ | | | | | | | | | | | | |
| Thermostat / Pressure [2] | 26/63 | | | | | ☐ | ☐ | ☐ | ☐ | | ☐ | ☐ | | ☐ | | | |
| Temperature monitoring (16 RTDs) [3] | 38/49T | | | | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | | ☐ |
| Sync-check [4] | 25 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | | | ☐ | ☐ | ☐ | ☐ | ☐ | |
| **Control and Monitoring** | | | | | | | | | | | | | | | | | |
| Circuit breaker / contactor control | 94/69 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Automatic transfer (AT) [2] | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | | | | ☐ | ☐ | ☐ | ☐ | ☐ | |
| Load shedding / automatic restart | | | | | | | | | ■ | ■ | ■ | | | | | | |
| De-excitation | | | | | | | | | | | | ■ | ■ | ■ | | | |
| Genset shutdown | | | | | | | | | | | | ■ | ■ | ■ | | | |
| Capacitor step control [2] | | | | | | | | | | | | | | | | | ☐ |
| Zone Selective Interlocking [2] | 68 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Latching / acknowledgement | 86 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Annunciation | 30 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Switching of groups of settings | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Adaptation using logic equations | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Logipam programming (Ladder language) | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

*The figures indicate the number of relays available for each protection function.*

■ *standard,* ☐ *options.*

***(1)*** *Protection functions with two groups of settings.*

***(2)*** *According to parameter setting and optional MES120 input/output modules.*

***(3)*** *With optional MET1482 temperature input modules.*

***(4)*** *With optional MCS025 sync-check module.*

# Selection Table

| | | Substation | | | | Transformer | | | Motor | | | Generator | | | Bus | | Cap. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metering** | | **S80** | **S81** | **S82** | **S84** | **T81** | **T82** | **T87** | **M81** | **M87** | **M88** | **G82** | **G87** | **G88** | **B80** | **B83** | **C86** |
| Phase current Ia, Ib, Ic, RMS | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Measured residual current Ir, calculated IrΣ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Demand current Ia, Ib, Ic | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Peak demand current Iamax, Ibmax, Icmax | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Measured residual current I'r | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| Voltage Vab, Vbc, Vac, Van, Vbn, Vcn | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Residual voltage Vr | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Positive sequence voltage V1 / rotation direction | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Negative sequence voltage V2 | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Frequency f | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Active power P, Pa, Pb, Pc | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Reactive power Q, Qa, Qb, Qc | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Apparent power S, Sa, Sb, Sc | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Peak demand power Pmax, Qmax | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Power factor pf | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Calculated active and reactive energy (±Wh, ±VARh) | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Active and reactive energy by pulse counting (2) (± Wh, ± VARh) | | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| Phase current I'a, I'b, I'c, RMS | | | | | | | | ■ | | ■ | ■ | | ■ | ■ | | | |
| Calculated residual current I'rΣ | | | | | | | | ■ | | ■ | ■ | | ■ | ■ | | | |
| Voltage V'ab, V'an and frequency | | | | | | | | | | | | | | | ■ | | |
| Voltage V'ab, V'bc, V'ac, V'an, V'bn, V'cn, V'1, V'2, and frequency | | | | | | | | | | | | | | | | ■ | |
| Residual voltage V'r | | | | | | | | | | | | | | | | ■ | |
| Temperature (16 RTDs) (3) | | | | | | □ | □ | □ | □ | □ | □ | □ | □ | □ | | | □ |
| Rotation speed (2) | | | | | | | | | □ | □ | □ | □ | □ | □ | | | |
| Neutral point voltage Vnt | | | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| **Network and Machine Diagnosis** | | | | | | | | | | | | | | | | | |
| Tripping context | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Tripping current TripIa, TripIb, TripIc | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Phase fault and ground fault trip counters | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Unbalance ratio / negative sequence current I2 | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Harmonic distortion (thd), current (Ithd) and voltage (Vthd) | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Phase displacement φr, φ'r, φrΣ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Phase displacement φa, φb, φc | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Disturbance recording | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Thermal capacity used | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ |
| Remaining operating time before overload tripping | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ |
| Waiting time after overload tripping | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ |
| Running hours counter / operating time | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | ■ |
| Starting current and time | | | | | | | | | ■ | ■ | ■ | | | | | | |
| Start block time | | | | | | | | | ■ | ■ | ■ | | | | | | |
| Number of starts before blocking | | | | | | | | | ■ | ■ | ■ | | | | | | |
| Unbalance ratio / negative sequence current I'2 | | | | | | | | ■ | | ■ | ■ | | ■ | ■ | | | |
| Differential current Idiffa, Idiffb, Idiffc | | | | | | | | ■ | | ■ | ■ | | ■ | ■ | | | |
| Through current Ita, Itb, Itc | | | | | | | | ■ | | ■ | ■ | | ■ | ■ | | | |
| Current phase displacement θr | | | | | | | | ■ | | ■ | ■ | | ■ | ■ | | | |
| Apparent positive sequence impedance Z1 | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Apparent phase-to-phase impedances Zab Zbc, Zac | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Third harmonic voltage, neutral point (VntH3) or residual (VrH3) | | | | | | | | | | | | ■ | ■ | ■ | | | |
| Difference in amplitude, frequency and phase of voltages compared for sync-check (4) | | □ | □ | □ | □ | □ | □ | □ | | | | □ | □ | □ | □ | □ | |
| Capacitor unbalance current and capacitance | | | | | | | | | | | | | | | | | ■ |
| **Switchgear Diagnosis** | **ANSI Code** | | | | | | | | | | | | | | | | |
| CT / VT supervision | 60/60FL | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Trip circuit supervision (2) | 74 | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| Auxiliary power supply monitoring | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Cumulative breaking current | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Number of operations, operating time, charging time, number of racking out operations (2) | | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| **Modbus, IEC 60870-5-103 or DNP3 Communication*** | | | | | | | | | | | | | | | | | |
| Measurement readout (5) | | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| Remote indication and time tagging of events (5) | | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| Remote control commands (5) | | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| Remote protection setting (5) | | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |
| Transfer of disturbance recording data (5) | | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ | □ |

■ *standard,* □ *options.*

*(2) According to parameter setting and optional MES120 input/output modules.*

*(3) With optional MET1482 temperature input modules.*

*(4) With optional MCS025 sync-check module.*

*(5) With ACE9492, ACE959, ACE937, ACE969TP or ACE969FO communication interface.*

***Note :*** ** Modbus, IEC60870-5-103, or DNP3 are available using ACE9492, ACE 959, ACE937, ACE969TP or ACE969FO.*

# Technical Characteristics

## Weight

| | Base Unit with Advanced UMI | Base Unit with Mimic-Based UMI |
|---|---|---|
| Minimum weight (base unit without MES120) | 5.29 lb. (2.4 kg) | 6.61 lb. (3.0 kg) |
| Maximum weight (base unit with 3 MES120) | 8.82 lb. (4.0 kg) | 10.1 lb. (4.6 kg) |

## Instrument Transformer Inputs

| **Phase Current Inputs** | **1A or 5A CT** |
|---|---|
| Input impedance | < 0.02 Ω |
| Burden | < 0.02 VA (1A CT)<br>< 0.5 VA (5A CT) |
| Continuous thermal withstand | 4 In |
| 1 second overload | 100 In |

| **Voltage Inputs** | **Phase** | **Residual** |
|---|---|---|
| Input impedance | > 100 kΩ | > 100 kΩ |
| Burden | < 0.015 VA (100 V VT) | < 0.015 VA (100 V VT) |
| Continuous thermal withstand | 240 V | 240 V |
| 1-second overload | 480 V | 480 V |
| Isolation of inputs from other isolated groups | Enhanced | Enhanced |

## Relay Outputs

### Control Relay Outputs O1 to O4 and Ox01 [1]

| | | | | | |
|---|---|---|---|---|---|
| Voltage | DC | 24/48 V DC | 125 V DC | 250 V DC | |
| | AC (47.5 to 63 Hz) | | | | 100 to 240 V AC |
| Continuous current | | 8 A | 8 A | 8 A | 8 A |
| Breaking capacity | Resistive load | 8 A / 4 A | 0.7 A | 0.3 A | |
| | Load L/R < 20 ms | 6 A / 2 A | 0.5 A | 0.2 A | |
| | Load L/R < 40 ms | 4 A / 1 A | 0.2 A | 0.1 A | |
| | Resistive load | | | | 8 A |
| | Load p.f. > 0.3 | | | | 5 A |
| Making capacity | | < 15 A for 200 ms | | | |
| Isolation of outputs from other isolated groups | | Enhanced | | | |

### Annunciation Relay Outputs O5 and Ox02 to Ox06

| | | | | | |
|---|---|---|---|---|---|
| Voltage | DC | 24/48 V DC | 127 V DC | 220 V DC | |
| | AC (47.5 to 63 Hz) | | | | 100 to 240 V AC |
| Continuous current | | 2 A | 2 A | 2 A | 2 A |
| Breaking capacity | L/R load < 20 ms | 2 A / 1 A | 0.5 A | 0.15 A | |
| | Load p.f. > 0.3 | | | | 1 A |
| Isolation of outputs from other isolated groups | | Enhanced | | | |

## Power Supply

| | | |
|---|---|---|
| Voltage | 24 to 250 V DC | –20 % / +10 % |
| Maximum burden | < 16 W | |
| Inrush current | < 10 A 10 ms | |
| Acceptable ripple content | 12 % | |
| Acceptable momentary outages | 100 ms | |

## Battery

| | |
|---|---|
| Format | 1/2 AA lithium 3.6 V |
| Service life | 10 years Sepam™ energized |
| | 8 years Sepam™ not energized |

*(1) Relay outputs comply with clause 6.7 of standard C37.90, (30 A, 200 ms, 2000 operations).*

# Environmental Characteristics

| **Electromagnetic Compatibility** | **Standard** | **Level / Class** | **Value** |
|---|---|---|---|
| **Emission Tests** | | | |
| Disturbing field emission | IEC 60255-25 | | |
| | EN 55022 | A | |
| Conducted disturbance emission | IEC 60255-25 | | |
| | EN 55022 | A | |
| **Immunity Tests – Radiated Disturbances** | | | |
| Immunity to radiated fields | ANSI C37.90.2 (1995) | | 35 V/m; 25 MHz - 1 GHz |
| | IEC 60255-22-3 | III | 10 V/m; 80 MHz - 1 GHz |
| | IEC 61000-4-3 | | 10 V/m; 80 MHz - 2 GHz |
| Electrostatic discharge | ANSI C.37.90.3 | | 8 kV air; 4 kV contact |
| | IEC 60255-22-2 | | 8 kV air; 6 kV contact |
| Immunity to magnetic fields at network frequency | IEC 61000-4-8 | 4 | 30 A/m (continuous) - 300 A/m (1 - 3 s) |
| **Immunity Tests – Conducted Disturbances** | | | |
| Immunity to conducted RF disturbances | IEC 60255-22-6 | III | 10 V |
| Fast transient bursts | ANSI C37.90.1 | | 4 kV; 2.5 kHz |
| | IEC 60255-22-4 | A and B | 4 kV; 2.5 kHz / 2 kV; 5 kHz |
| | IEC 61000-4-4 | IV | 4 kV; 2.5 kHz |
| 1 MHz damped oscillating wave | ANSI C37.90.1 | | 2.5 kV; 2.5 kHz |
| | IEC 60255-22-1 | | 2.5 kV CM; 1kV DM |
| Surges | IEC 61000-4-5 | III | 2 kV CM; 1 kV DM |
| Voltage interruptions | IEC 60255-11 | | 100 % during 100 ms |
| **Mechanical Robustness** | **Standard** | **Level / Class** | **Value** |
| **In Operation** | | | |
| Vibrations | IEC 60255-21-1 | 2 | 1 Gn; 10 Hz - 150 Hz |
| | IEC 60068-2-6 | Fc | 2 Hz - 13.2 Hz ; a = ±1 mm |
| Shocks | IEC 60255-21-2 | 2 | 10 Gn / 11 ms |
| Groundquakes | IEC 60255-21-3 | 2 | 2 Gn (horizontal axes) |
| | | | 1 Gn (vertical axes) |
| **De-Energized** | | | |
| Vibrations | IEC 60255-21-1 | 2 | 2 Gn; 10 Hz - 150 Hz |
| Shocks | IEC 60255-21-2 | 2 | 27 Gn / 11 ms |
| Jolts | IEC 60255-21-2 | 2 | 20 Gn / 16 ms |
| **Climatic Withstand** | **Standard** | **Level / Class** | **Value** |
| **In Operation** | | | |
| Exposure to cold | IEC 60068-2-1 | Ad | –25 °C (–13 °F) |
| Exposure to dry heat | IEC 60068-2-2 | Bd | +70 °C (+158 °F) |
| Continuous exposure to damp heat | IEC 60068-2-78 | Cab | 10 days; 93 % RH; 40 °C (104 °F) |
| Salt mist | IEC 60068-2-52 | Kb/2 | 6 days |
| Influence of corrosion/Gas test 2 | IEC 60068-2-60 | | 21 days; 75 % RH; 25 °C (77 °F);<br>0.5 ppm $H_2S$; 1 ppm $SO_2$ |
| Influence of corrosion/Gas test 4 | IEC 60068-2-60 | | 21 days; 75 % RH; 25 °C (77 °F);<br>0.01 ppm $H_2S$; 0.2 ppm $SO_2$;<br>0.2 ppm $NO_2$; 0.01 ppm $Cl_2$ |
| **In Storage** (3) | | | |
| Temperature variation with specified variation rate | IEC 60068-2-14 | Nb | –25 °C to +70 °C, (–13 °F to +158 °F)<br>5 °C/min |
| Exposure to cold | IEC 60068-2-1 | Ab | –25 °C (–13 °F) |
| Exposure to dry heat | IEC 60068-2-2 | Bb | +70 °C (+158 °F) |
| Continuous exposure to damp heat | IEC 60068-2-78 | Cab | 56 days; 93 % RH; 40 °C (104 °F) |
| | IEC 60068-2-30 | Db | 6 days; 95 % RH; 55 °C (131 °F) |
| **Safety** | **Standard** | **Level / Class** | **Value** |
| **Enclosure Safety Tests** | | | |
| Front panel tightness | IEC 60529 | IP52 | Other panels IP20 |
| | NEMA | Type 12 | |
| Fire withstand | IEC 60695-2-11 | | 650 °C (1200 °F) with glow wire |
| **Electrical Safety Tests** | | | |
| 1.2/50 µs impulse wave | IEC 60255-5 | | 5 kV (1) |
| Power frequency dielectric withstand | ANSI C37.90 | | 1 kV 1 min (indication output)<br>1.5 kV 1 min (control output) |
| | IEC 60255-5 | | 2 kV 1 min (2) |
| **Certification** | | | |
| CE | EN 50263 harmonized standard | European directives:<br>■ 89/336/EECElectromagnetic Compatibility (EMC) Directive<br>□ 92/31/EECAmendment<br>□ 93/68/EECAmendment<br>■ 73/23/EECLow Voltage Directive<br>□ 93/68/EECAmendment | |
| UL | UL508 - CSA C22.2 no. 14-95 | | File E212533 |
| CSA | CSA C22.2 no. 14-95 / no. 94-M91 / no. 0.17-00 | | File 210625 |

*(1) Except for communication: 3 kV in common mode and 1 kV in differential mode.*

*(2) Except for communication: 1 kVrms.*

*(3) Sepam™ must be stored in its original packing.*

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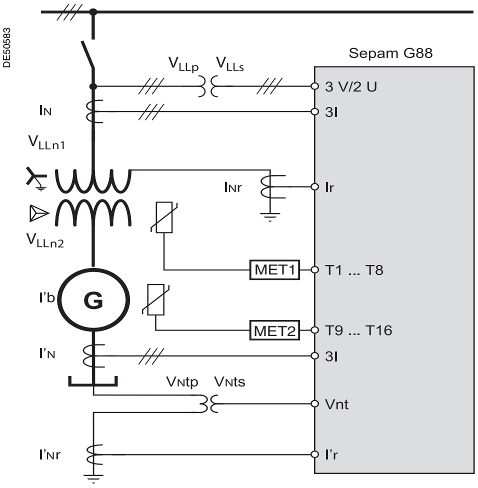
# Instrument Transformer Inputs



*Example of Sepam™ G88 instrument transformer inputs*

Sepam™ Series 80 has analog inputs that are connected to the measurement instrument transformers required for applications:

- main analog inputs, available on all types of Sepam™ Series 80:
  - three phase current inputs Ia, Ib, Ic
  - one residual current input Ir
  - three phase voltage inputs Van, Vbn, Vcn
  - one residual voltage input Vr
- additional analog inputs, dependent on the type of Sepam™:
  - three additional phase current inputs I'a, I'b, I'c
  - one additional residual current input I'r
  - three additional phase voltage inputs V'an, V'bn, Vcn
  - one additional residual voltage input V'r

The table below lists the analog inputs available according to the type of Sepam™ Series 80.

| | | **S80, S81, S82, S84** | **T81, T82, M81, G82** | **T87, M87, M88, G87, G88** | **B80** | **B83** | **C86** |
|---|---|---|---|---|---|---|---|
| Phase current inputs | Main channel | Ia, Ib, Ic | Ia, Ib, Ic | Ia, Ib, Ic | Ia, Ib, Ic | Ia, Ib, Ic | Ia, Ib, Ic |
| | Additional channels | | | I'a, I'b, I'c | | | |
| Residual current inputs | Main channel | Ir | Ir | Ir | Ir | Ir | Ir |
| | Additional channels | I'r | I'r | I'r | I'r | | |
| Unbalance current inputs for capacitor steps | | | | | | | I'a, I'b, I'c, I'r |
| Phase voltage inputs | Main channel | Van, Vbn, Vcn, or Vab, Vbc | Van, Vbn, Vcn, or Vab, Vbc | Van, Vbn, Vcn, or Vab, Vbc | Van, Vbn, Vcn, or Vab, Vbc | Van, Vbn, Vcn, or Vab, Vbc | Van, Vbn, Vcn, or Vab, Vbc |
| | Additional channels | | | | V'an or V'ab | V'a, V'b, V'c, or V'ab, V'bc | |
| Residual voltage inputs | Main channel | Vr | Vr | Vr | Vr (1) | Vr | Vr |
| | Additional channel | | | | | V'r | |
| Temperature inputs (on MET1482 module) | | | T1 to T16 | T1 to T16 | | | T1 to T16 |

***Note**: by extension, an additional measurement (current or voltage) is a value measured via an additional analog channel.*
***(1)** Available with phase voltage Vab, Vbc.*

# General Settings

The general settings define the characteristics of the measurement instrument transformers Sepam™ connects to. These settings also determine the performance of the metering and protection functions that Sepam™ uses. The user can access these settings in the SFT2841 setting software "General Characteristics", "CT-VT Sensors", and "Particular Characteristics" tabs.

| General Settings | | Selection | Value |
|---|---|---|---|
| IN, I'N | Rated phase current (instrument transformer primary current) | Two or three 1A / 5A CTs | 1 A to 6250 A |
| | | Three LPCTs | 25 A to 3150 A (1) |
| I'N | Unbalance current CT rating (capacitor application) | CT 1A / 2A / 5A | 1 A to 30 A |
| $I_B$ | Base current, according to rated power of equipment | | 0.2 to 1.3 In |
| $I'_B$ | Base current on additional channels (not adjustable) | Applications with transformer | $I'_B = I_B$ x $V_{LL}N1/V_{LL}N2$ |
| | | Other applications | $I'_B = I_B$ |
| INr, I'Nr | Rated residual current | Sum of three phase currents | See IN(I'N) rated phase current |
| | | CSH120 or CSH200 zero sequence CT | 2 A or 20 A rating |
| | | 1A / 5A CT | 1 A to 6250 A |
| | | Zero sequence CT + ACE990 (the zero sequence CT ratio 1/n must be such that 50 ≤ n ≤ 1500) | According to current monitored and use of ACE990 |
| $V_{LLp}$, $V'_{LLp}$ | Rated primary phase-to-phase voltage (Vnp: rated primary phase-to-neutral voltage Vnp = $V_{LLp}/\sqrt{3}$) | | 220 V to 250 kV |
| $V_{LLs}$, $V'_{LLs}$ | Rated secondary phase-to-phase voltage | 3 VTs: Van, Vbn, Vcn | 90 to 230 $V_{LL}$ |
| | | 2 VTs: Vab, Vbc | 90 to 230 $V_{LL}$ |
| | | 1 VT: Vab | 90 to 230 $V_{LL}$ |
| | | 1 VT: Van | 90 to 230 $V_{LL}$ |
| $V_{LLs}0$, $V'_{LLs}0$ | Secondary zero sequence voltage for primary zero sequence voltage $V_{LLp}/\sqrt{3}$ | | $V_{LLs}/3$ or $V_{LLs}/\sqrt{3}$ |
| Vntp | Neutral point voltage transformer primary voltage (generator application) | | 220 V to 250 kV |
| Vnts | Neutral point voltage transformer secondary voltage (generator application) | | 57.7 V to 133 V |
| fN | Rated frequency | | 50 Hz or 60 Hz |
| | Phase rotation direction | | a-b-c or a-c-b |
| | Integration period (for demand current and peak demand current and power) | | 5, 10, 15, 30, 60 min |
| | Pulse-type accumulated energy meter | Increments active energy | 0.1 kWh to 5 MWh |
| | | Increments reactive energy | 0.1 kVARh to 5 MVARh |
| P | Rated transformer power | | 100 kVA to 999 MVA |
| $V_{LL}N1$ | Rated winding a voltage (main channels: I) | | 220 V to 220 kV |
| $V_{LL}N2$ | Rated winding b voltage (additional channels: I') | | 220 V to 400 kV |
| IN1 | Rated winding a current (not adjustable) | | INa = P/($\sqrt{3}$ $V_{LL}N1$) |
| IN2 | Rated winding b current (not adjustable) | | INb = P/($\sqrt{3}$ $V_{LL}N2$) |
| | Transformer vector shift | | 0 to 11 |
| ωN | Rated speed (motor, generator) | | 100 to 3600 rpm |
| R | Number of pulses per rotation (for speed acquisition) | | 1 to 1800 (Ωn x R/60 ⩽ 1500) |
| | Zero speed set point | | 5 to 20 % of Ωn |
| | Number of capacitor steps | | 1 to 4 |
| | Connection of capacitor steps | | Wye / Delta |
| | Capacitor step ratio | Step 1 | 1 |
| | | Step 2 | 1, 2 |
| | | Step 3 | 1, 2, 3, 4 |
| | | Step 4 | 1, 2, 3, 4, 6, 8 |

*(1) In values for LPCT, in Amps: 25, 50, 100, 125, 133, 200, 250, 320, 400, 500, 630, 666, 1000, 1600, 2000, 3150*

| Functions | | Measurement Range | Accuracy (1) | MSA141 | Saving |
|---|---|---|---|---|---|
| **Metering** | | | | | |
| Phase current | | 0.02 to 40 IN | ±0.5 % | ■ | |
| Residual current | Calculated | 0.005 to 40 IN | ±1 % | ■ | |
| | Measured | 0.005 to 20 INN | ±1 % | ■ | |
| Demand current | | 0.02 to 40 IN | ±0.5 % | | |
| Peak demand current | | 0.02 to 40 IN | ±0.5 % | | □ |
| Phase-to-phase voltage | Main channels (V) | 0.05 to 1.2 $V_{(L-L)}$p | ±0.5 % | ■ | |
| | Additional channels (V’) | 0.05 to 1.2$V_{(L-L)}$p | ±1 % | | |
| Phase-to-neutral voltage | Main channels (Van, Vbn, Vcn) | 0.05 to 1.2 $V_{(L-n)}$p | ±0.5 % | ■ | |
| | Additional channels (V’an, Vbn, V’cn) | 0.05 to 1.2 $V_{(L-n)}$p | ±1 % | | |
| Residual voltage | | 0.015 to 3 $V_{(L-n)}$p | ±1 % | | |
| Neutral point voltage | | 0.015 to 3 Vntp | ±1 % | | |
| Positive sequence voltage | | 0.05 to 1.2 Vnp | ±2 % | | |
| Negative sequence voltage | | 0.05 to 1.2 Vnp | ±2 % | | |
| Frequency | Main channels (f) | 25 to 65 Hz | ±0.01 Hz | ■ | |
| | Additional channels (f’) | 45 to 55 Hz (fn = 50 Hz)<br>55 to 65 Hz (fn = 60 Hz) | ±0.05 Hz | | |
| Active power (total or per phase) | | 0.008 Sn to 999 MW | ±1 % | ■ | |
| Reactive power (total or per phase) | | 0.008 Sn to 999 MVAR | ±1 % | ■ | |
| Apparent power (total or per phase) | | 0.008 Sn to 999 MVA | ±1 % | ■ | |
| Peak demand active power | | 0.008 Sn to 999 MW | ±1 % | | □ |
| Peak demand reactive power | | 0.008 Sn to 999 MVAR | ±1 % | | □ |
| Power factor | | –1 to + 1 (CAP/IND) | ±0.01 | ■ | |
| Calculated active energy | | 0 to 2.1 x $10^8$ MWh | ±1 % ±1 digit | | □ □ |
| Calculated reactive energy | | 0 to 2.1 x $10^8$ MVARh | ±1 % ±1 digit | | □ □ |
| Temperature | | –30 °C to +200 °C<br>or –22 °F to +392 °F | ±1 °C from +20 to +140 °C | ■ | |
| Rotation speed | | 0 to 7200 rpm | ±1 rpm | | |
| **Network Diagnosis Assistance** | | | | | |
| Tripping context | | | | | □ |
| Tripping current | | 0.02 to 40 IN | ±5 % | | □ |
| Number of trips | | 0 to 65535 | - | | □ □ |
| Negative sequence / unbalance | | 1 to 500 % of $I_B$ | ±2 % | | |
| Total harmonic distortion, current | | 0 to 100 % | ±1 % | | |
| Total harmonic distortion, voltage | | 0 to 100 % | ±1 % | | |
| Phase displacement φr (between Vr and Ir) | | 0 to 359° | ±2° | | |
| Phase displacement φa, φb, φc (between V and I) | | 0 to 359° | ±2° | | |
| Disturbance recording | | | | | □ |
| Amplitude difference | | 0 to 1.2 $V_{LL}$sync1 | ±1 % | | |
| Frequency difference | | 0 to 10 Hz | ±0.5 Hz | | |
| Phase difference | | 0 to 359° | ±2° | | |
| Out-of-sync context | | | | | □ |

■ *available on MSA141 analog output module, according to setup*

□ □ *saved in the event of auxiliary supply outage, even without battery*

□ *saved by battery in the event of auxiliary supply outage*

***(1)*** *Typical accuracy, see details on subsequent pages*

| Functions | Measurement Range | Accuracy (1) | MSA141 | Saving |
|---|---|---|---|---|
| **Machine Operating Assistance** | | | | |
| Thermal capacity used | 0 to 800 %<br>(100 % for phase $I = I_B$) | ±1 % | ■ | □ □ |
| Remaining operating time before overload tripping | 0 to 999 min | ±1 min | | |
| Waiting time after overload tripping | 0 to 999 min | ±1 min | | |
| Running hours counter / operating time | 0 to 65535 hours | ±1 % or ±0.5 h | | □ □ |
| Starting current | 1.2 Ib to 40 IN | ±5 % | | □ |
| Starting time | 0 to 300 s | ±300 ms | | □ |
| Number of starts before blocking | 0 to 60 | | | |
| Start block time | 0 to 360 min | ±1 min | | |
| Differential current | 0.015 to 40 IN | ±1 % | | |
| Through current | 0.015 to 40 IN | ±1 % | | |
| Phase displacement θa, θb, θc (between I and I') | 0 to 359° | ±2° | | |
| Apparent impedance Z1, Zab, Zbc, Zac | 0 to 200 kΩ | ±5 % | | |
| Third harmonic neutral point voltage VntH3 | 0.2 to 30 % of $V_{Ln}$p | ±1 % | | |
| Third harmonic residual voltage VrH3 | 0.2 to 90 % of $V_{Ln}$p | ±1 % | | |
| Capacitance | 0 to 30 F | ±5 % | | |
| Capacitor unbalance current | 0.02 to 40 I'N | ±5 % | | |
| **Switchgear Diagnosis Assistance** | | | | |
| Cumulative breaking current | 0 to 65535 kA$^2$ | ±10 % | | □ □ |
| Number of operations | 0 to 4 x $10^9$ | - | | □ □ |
| Operating time | 20 to 100 s | ±1 ms | | □ □ |
| Charging time | 1 to 20 s | ±0.5 s | | □ □ |
| Number of rackouts | 0 to 65535 | - | | □ □ |

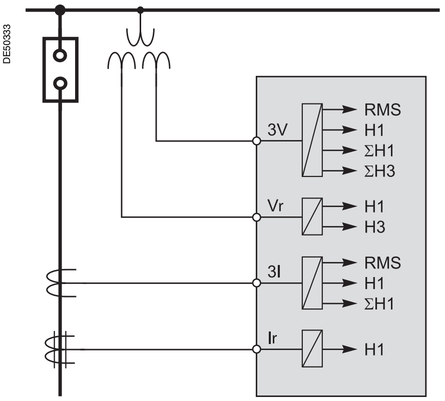
■ *available on MSA141 analog output module, according to setup*

□ □ *saved in the event of auxiliary supply outage, even without battery*

□ *saved by battery in the event of auxiliary supply outage*

***(1)** Typical accuracy. See details on subsequent pages.*

# Processing Measured Signals



*Values produced by Sepam™ from the signals measured*

## Measured Physical Values

Sepam™ measures the following physical values:

- phase currents (3I)
- residual current (Ir)
- phase voltages (3V)
- residual voltage (Vr)

Sepam™ processes each measured signal to produce all the values necessary for metering, diagnosis and protection.

The charts below identify (according to the various functions) the values produced from the signals measured, with:

- RMS = RMS value up to the 13th harmonic
- H1 = fundamental 50 Hz or 60 Hz component
- ΣH1 = vector sum of the fundamental components of the three phases
- H3 = 3rd harmonic component
- ΣH3 = vector sum of the 3rd harmonic components of the three phases.

## Values Used by the Metering and Diagnosis Functions

| | | **3I** | | | **Ir** | **3V** | | | | **Vr** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metering** | | **RMS** | **H1** | **ΣH1** | **H1** | **RMS** | **H1** | **ΣH1** | **ΣH3** | **H1** | **H3** |
| RMS phase current Ia, Ib, Ic | | ■ | | | | | | | | | |
| Calculated residual current IrΣ | | | | ■ | | | | | | | |
| Demand current Ia, Ib, Ic | | ■ | | | | | | | | | |
| Peak demand current Iamax, Ibmax, Icmax | | ■ | | | | | | | | | |
| Measured residual current Ir, I'r | | | | | ■ | | | | | | |
| Voltage Vab, Vbc, Vac, Van, Vbn, Vcn, V'ab, V'bc, V'ac, V'an, V'bn, V'cn | | | | | | | ■ | | | | |
| Residual voltage Vr | | | | | | | | □ | | □ | |
| Positive sequence voltage V1 / rotation direction | | | | | | | ■ | | | | |
| Negative sequence voltage V2 | | | | | | | ■ | | | | |
| Frequency f | | | | | | | ■ | | | | |
| Active power P, Pa, Pb, Pc | | | ■ | | | | ■ | | | | |
| Reactive power Q, Qa, Qb, Qc | | | ■ | | | | ■ | | | | |
| Apparent power S, Sa, Sb, Sc | | | ■ | | | | ■ | | | | |
| Peak demand power Pmax, Qmax | | | ■ | | | | ■ | | | | |
| Power factor (pf) | | | ■ | | | | ■ | | | | |
| Calculated active and reactive energy (± Wh, ± VARh) | | | ■ | | | | ■ | | | | |
| Phase current I'a, I'b, I'c RMS | | ■ | | | | | | | | | |
| Calculated residual current I'rΣ | | | | ■ | | | | | | | |
| Neutral point voltage $V_{L}$nt | | | | | | | | | | ■ | |
| **Network and Machine Diagnosis** | | | | | | | | | | | |
| Tripping current TripIa, TripIb, TripIc | | | ■ | | | | | | | | |
| Unbalance ratio / negative sequence current I2 | | | ■ | | | | | | | | |
| Harmonic distortion (THD), current Ithd | | ■ | ■ | | | | | | | | |
| Harmonic distortion (THD), voltage Vthd | | | | | | ■ | ■ | | | | |
| Phase displacement φr, φ'r, φrΣ | | | | ■ | ■ | | | □ | | □ | |
| Phase displacement φa, φb, φc | | | ■ | | | | ■ | | | | |
| Thermal capacity used | | ■ | | | | | | | | | |
| Unbalance ratio / negative sequence current I'2 | | | ■ | | | | | | | | |
| Differential current Idiffa, Idiffb, Idiffc | | | ■ | | | | | | | | |
| Through current Ita, Itb, Itc | | | ■ | | | | | | | | |
| Angle between currents I and I' | | | ■ | | | | | | | | |
| Starting current | | | ■ | | | | | | | | |
| Third harmonic voltage, neutral point or residual VntH3 | | | | | | | | | ■ | | ■ |
| **Switchgear Diagnosis** | **ANSI Code** | | | | | | | | | | |
| CT / VT supervision | 60/60FL | | ■ | | | | ■ | | | | |
| Cumulative breaking current | | | ■ | | | | | | | | |

■ *standard*
□ *according to instrument transformers connected*

## Values Used by the Protection Functions

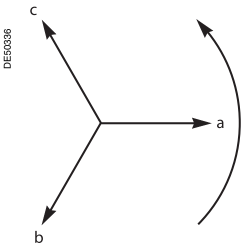
| | | 3I | | | I0 | 3V | | | | V0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Protections** | **ANSI Code** | **RMS** | **H1** | **ΣH1** | **H1** | **RMS** | **H1** | **ΣH1** | **ΣH3** | **H1** | **H3** |
| Phase overcurrent | 50/51 | | ■ | | | | | | | | |
| Ground fault<br>Sensitive ground fault | 50N/51N<br>50G/51G | | | □ | □ | | | | | | |
| Breaker failure | 50BF | | ■ | | | | | | | | |
| Negative sequence / current unbalance | 46 | | ■ | | | | | | | | |
| Thermal overload for cables | 49RMS | ■ | | | | | | | | | |
| Thermal overload for machines | 49RMS | ■ | | | | | | | | | |
| Thermal overload for capacitors | 49RMS | ■ | | | | | | | | | |
| Capacitor bank unbalance | 51C | | ■ | | | | | | | | |
| Restricted ground fault | 64REF | | | ■ | ■ | | | | | | |
| Two-winding transformer differential | 87T | | ■ | | | | | | | | |
| Machine differential | 87M | | ■ | | | | | | | | |
| Directional phase overcurrent | 67 | | ■ | | | | ■ | | | | |
| Directional ground fault | 67N/67NC | | | □ | □ | | | □ | | □ | |
| Directional active overpower | 32P | | ■ | | | | ■ | | | | |
| Directional reactive overpower | 32Q | | ■ | | | | ■ | | | | |
| Directional active underpower | 37P | | ■ | | | | ■ | | | | |
| Phase undercurrent | 37 | | ■ | | | | | | | | |
| Excessive starting time, locked rotor | 48/51LR | | ■ | | | | | | | | |
| Starts per hour | 66 | | ■ | | | | | | | | |
| Field loss (underimpedance) | 40 | | ■ | | | | ■ | | | | |
| Pole slip | 78 PS | | ■ | | | | ■ | | | | |
| Voltage-restrained overcurrent | 50V/51V | | ■ | | | | ■ | | | | |
| Underimpedance | 21B | | ■ | | | | ■ | | | | |
| Inadvertent energization | 50/27 | | ■ | | | | ■ | | | | |
| Third harmonic undervoltage /<br>100 % stator ground fault | 27TN/64G2<br>64G | | | | | | | | □ | | ■ |
| Overexcitation (V / Hz) | 24 | | | | | | ■ | | | | |
| Positive sequence undercurrent | 27D | | | | | | ■ | | | | |
| Remnant undervoltage | 27R | | | | | | ■ | | | | |
| Undervoltage (L-L or L-n) | 27 | | | | | | ■ | | | | |
| Overvoltage (L-L or L-n) | 59 | | | | | | ■ | | | | |
| Neutral voltage displacement | 59N | | | | | | | □ | | □ | |
| Negative sequence overvoltage | 47 | | | | | | ■ | | | | |
| Overfrequency | 81H | | | | | | ■ | | | | |
| Underfrequency | 81L | | | | | | ■ | | | | |
| Rate of change of frequency | 81R | | | | | | ■ | | | | |

■ *standard*
□ *according to instrument transformers connected*

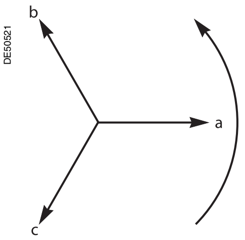
## Phase Rotation Direction

The rotation direction of the three phases may be a-b-c, or a-c-b, the phase order in the trigonometric (counterclockwise) direction.

The phase rotation direction should be set for correct calculation of the symmetrical components (Va, Vb, VrΣ, Ia, Ib, IrΣ).



*Phase rotation direction a-b-c*



*Phase rotation direction a-c-b*

# Phase Current/Residual Current

## Phase Current

### Operation

This function provides an RMS value for the phase currents:

- Ia: phase a current, main channels
- Ib: phase b current, main channels
- Ic: phase c current, main channels
- I’a: phase a current, additional channels
- I’b: phase b current, additional channels
- I’c: phase c current, additional channels

It is based on RMS current measurement and considers up to the13th harmonic.
Different types of current transformers (CTs) can monitor phase current:

- 1A or 5A current transformers
- Low Power Current Transducer (LPCT) type current sensors

### Readout

Access to the measurements is by one of the following:

- Sepam™ display via the ⏲ key
- a PC loaded with SFT2841 software
- a communication link
- an analog converter with the MSA141 option

### Characteristics

| | |
|---|---|
| Measurement range | 0.02 to 40 $I_N$ (1) |
| Units | A or kA |
| Resolution | 0.1 A |
| Accuracy | ±0.5 % typical (2)<br>±1 % from 0.3 to 1.5 $I_N$<br>±2 % from 0.1 to 0.3 $I_N$ |
| Display format | 3 significant digits |
| Refresh interval | 1 second (typical) |

***(1)** In rated current set in the general settings*
***(2)** At In, under reference conditions (IEC 60255-6)*

## Residual Current

### Operation

This operation provides an RMS value of the residual current. It is based on measuring the fundamental component. Four types of residual current values are available, depending on the type of Sepam™ and CTs connected:

- two residual currents, IrΣ and I'rΣ, which are calculated by the vectoral sum of the three phase currents
- two measured residual currents, Ir and I'r

Different types of CTs can be used to measure residual current:

- CSH120 or CSH200 specific zero sequence CT
- conventional 1A or 5A current transformer
- any zero sequence CT with an ACE990 interface.

### Readout

Access to the measurements is by one of the following:

- a Sepam™ display via the ⏲ key
- a PC with SFT2841 software
- a communication link
- an analog converter with the MSA141 option.

### Characteristics

| | | | | |
|---|---|---|---|---|
| Measurement range | IrΣ or I’rΣ | | | 0.005 to 40 $I_N$ (1) |
| | Ir or I’r measured by CSH zero sequence CT | Rating | $I_{Nr}$ = 2 A | 0.005 to 20 $I_{Nr}$ (1) |
| | | | $I_{Nr}$ = 20 A | 0.005 to 20 $I_{Nr}$ (1) |
| | Ir or I’r measured by zero sequence CT with ACE990 | | | 0.005 to 20 $I_{Nr}$ (1) |
| | Ir or I’r measured by CT | | | 0.005 to 20 $I_{Nr}$ (1) |
| Units | | | | A or kA |
| Resolution | | | | 0.1 A or 1 digit |
| Accuracy (2) | | | | ±1 % typical at In0<br>±2 % from 0.3 to 1.5 $I_{Nr}$<br>±5 % from 0.1 to 0.3 $I_{Nr}$ |
| Display format | | | | 3 significant digits |
| Refresh interval | | | | 1 second (typical) |

***(1)** $I_N$, $I_{Nr}$: nominal rating set in the general settings.*
***(2)** Under reference conditions (IEC 60255-6), excluding CT accuracy.*

# Demand Current/ Peak Demand Currents

## Operation

Demand current and peak demand currents are calculated according to the three phase currents Ia, Ib, and Ic:

- demand current is calculated over an adjustable period, usually 5 to 60 minutes
- peak demand current is the greatest demand current and indicates the current drawn by peak loads

Peak demand current values can be cleared. They are saved in the event of power loss.

## Readout

Access the measurements by any of the following:

- the Sepam™ display via the key
- a PC with SFT2841 software
- a communication link.

## Resetting to Zero

The user can access zero reset:

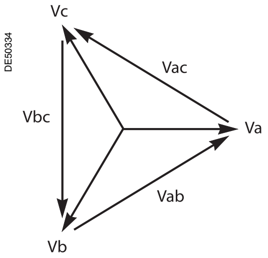
- via the **clear button** on the Sepam™ display if a peak demand is displayed
- via the **clear command** in the SFT2841 software
- via the communication link (remote control command TC4)

## Characteristics

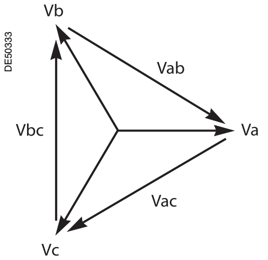
| | |
|---|---|
| Measurement range | 0.02 to 40 $I_N$ (1) |
| Units | A or kA |
| Resolution | 0.1 A |
| Accuracy | ±0.5 % typical (2)<br>±1 % from 0.3 to 1.5 $I_N$<br>±2 % from 0.1 to 0.3 $I_N$ |
| Display format | 3 significant digits |
| Integration period | 5, 10, 15, 30, 60 min |

***(1)** $I_N$ rated current set in the general settings.*
***(2)** At $I_N$, under reference conditions (IEC 60255-6).*

# Phase-to-Phase Voltage



*a-b-c network: phase-to-neutral and phase-to-phase voltages*



*a-c-b network: phase-to-neutral and phase-to-phase voltages*

## Operation

This function gives the RMS value of the fundamental 50 Hz or 60 Hz component of:

- the main phase-to-phase voltages:
  - ☐ $(\vec{V}ab = \vec{V}a - \vec{V}b)$ , voltage between phases a and b
  - ☐ $(\vec{V}bc = \vec{V}b - \vec{V}c)$ , voltage between phases b and c
  - ☐ $(\vec{V}ca = \vec{V}c - \vec{V}a)$ , voltage between phases a and c
- the additional phase-to-phase voltages:
  - ☐ $(\vec{V'}ab = \vec{V'}a - \vec{V'}b)$ , voltage between phases a and b
  - ☐ $(\vec{V'}bc = \vec{V'}b - \vec{V'}c)$ , voltage between phases b and c
  - ☐ $(\vec{V'}ac = \vec{V'}a - \vec{V'}c)$ , voltage between phases a and c

## Readout

Access to the measurements is by one of the following:

- the Sepam™ display via the ◔ key
- a PC with SFT2841 software
- communication link
- an analog converter with the MSA141 option

## Characteristics

| | |
|---|---|
| Measurement range | 0.05 to 1.2 $V_{LL}$p (1) |
| Units | V or kV |
| Resolution | 1 V |
| Accuracy | ±0.5 % typical (2) main channels<br>±1 % typical (2) additional channels<br>±1 % from 0.5 to 1.2 $V_{LLp}$<br>±2 % from 0.06 to 0.5 $V_{LLp}$ |
| Display format | 3 significant digits |
| Refresh interval | 1 second (typical) |

***(1)** Set in the general settings*
***(2)** At $V_{LL}$p, under reference conditions (IEC 60255-6)*

# Phase-to-Neutral Voltage

## Operation

This function gives the RMS value of the fundamental 50 Hz or 60 Hz component of:

- the main phase-to-neutral voltages Van, Vbn, and Vcn, measured on phases a, b, and c
- the additional phase-to-neutral voltages V'an, V'bn, and V'cn, measured on phases a, b, and c

## Readout

Access to the measurements is by one of the following:

- the Sepam™ display via the key
- a PC with SFT2841 software
- the communication link
- an analog converter with the MSA141 option

## Characteristics

| | |
|---|---|
| Measurement Range | 0.05 to 1.2 $V_{(L-n)p}$ **(1)** |
| Units | V or kV |
| Resolution | 1 V |
| Accuracy | ±0.5 % typical **(2)** main channels<br>±1 % typical **(2)** additional channels<br>±1 % from 0.5 to 1.2 $V_{Ln}p$<br>±2 % from 0.06 to 0.5 $V_{Ln}p$ |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1)*** $V_{(L-n)p}$*: primary rated phase-to-neutral voltage (*$V_{(L-n)p} = V_{LL}p/\sqrt{3}$*)*
***(2)*** *At* $V_{Ln}p$*, under reference conditions (IEC 60255-6)*

# Residual Voltage
# Neutral Point Voltage

## Residual Voltage

### Operation

This function provides the following values:

- main residual voltage $\vec{V}\mathrm{r} = \vec{V}\mathrm{an} + \vec{V}\mathrm{bn} + \vec{V}\mathrm{cn}$
- additional residual voltage $\vec{V'}\mathrm{r} = \vec{V'}\mathrm{an} + \vec{V'}\mathrm{bn} + \vec{V'}\mathrm{cn}$

Calculating residual voltage occurs in one of two ways:

- by an broken wye/delta voltage transformer (VT)
- by taking the internal vector sum of the three phase voltages

Measure the fundamental 50 Hz or 60 Hz component of the voltages to obtain the residual voltage value.

### Readout

Access to the measurements is by one of the following:

- the Sepam™ display via the ⏲ key
- a PC with SFT2841 software
- communication link

### Characteristics

| | |
|---|---|
| Measurement Range | 0.015 to 3 $V_{(L-n)p}$ (1) |
| Units | V or kV |
| Resolution | 1 V |
| Accuracy | ±1 % from 0.5 to 3 $V_{(L-L)p}$<br>±2 % from 0.05 to 0.5 $V_{(L-L)p}$<br>±5 % from 0.02 to 0.05 $V_{(L-L)p}$ |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1)*** *$V_{Ln}$p: primary rated phase-to-neutral voltage ($V_{Ln}$p = $V_{(L-n)p}/\sqrt{3}$)*

## Neutral Point Voltage

### Operation

This function gives the value of the zero sequence voltage *Vnt*, measured at the neutral point of a generator or motor by a dedicated VT:

$$\vec{V}\mathbf{nt} = (\vec{V}\mathrm{an} + \vec{V}\mathrm{bn} + \vec{V}\mathrm{cn'})/3$$

### Readout

Access the measurements through:

- the Sepam™ display via the ⏲ key
- a PC with SFT2841 software
- the communication link

### Characteristics

| | |
|---|---|
| Measurement Range | 0.015 to 3 $V_{Ln}$p (1) |
| Units | V or kV |
| Resolution | 1 V |
| Accuracy | ±1 % from 0.5 to 3 $V_{Ln}$p<br>±2 % from 0.05 to 0.5 $V_{Ln}$p<br>±5 % from 0.02 to 0.05 $V_{Ln}$p |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1) $V_{Ln}$p*** *is an abbreviation that refers to neutral point voltage transformer primary voltage*

# Positive Sequence Voltage

## Operation

This function calculates the value of the main positive sequence voltage V1:

- from the three main phase-to-neutral voltages:
  - ☐ phase rotation direction a-b-c: $\vec{V}1 = \frac{1}{3} \times (\vec{V}an + a\vec{V}bn + a^2\vec{V}cn)$
  - ☐ phase rotation direction a-c-b: $\vec{V}1 = \frac{1}{3} \times (\vec{V}an + a^2\vec{V}bn + a\vec{V}cn)$
- from the two main phase-to-phase voltages:
  - ☐ phase rotation direction a-b-c: $\vec{V}1 = \frac{1}{3} \times (\vec{V}ab - a^2\vec{V}bc)$
  - ☐ phase rotation direction a-c-b: $\vec{V}1 = \frac{1}{3} \times (\vec{V}ab - a\vec{V}bc)$

with $x = e^{j\frac{2\pi}{3}}$

The additional positive sequence voltage **V'1** is calculated the same way:

- from the three additional phase-to-neutral voltages V'an, V'bn, and V'cn
- from the two additional phase-to-phase voltages V'ab and V'bc

## Readout

Access to the measurements is by one of the following:

- the Sepam™ display via the key
- a PC with SFT2841 software
- communication link

## Characteristics

| | |
|---|---|
| Measurement Range | 0.05 to 1.2 $V_{Ln}$p **(1)** |
| Units | V or kV |
| Resolution | 1 V |
| Accuracy | ±2 % at $V_{Ln}$p |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1)*** *$V_{Ln}$p: primary rated phase-to-neutral voltage ($V_{LL}$p = $V_{Ln}$p/$\sqrt{3}$)*

# Negative Sequence Voltage

## Operation

This function calculates the value of the main negative sequence voltage *Vi*:

- from the three main phase-to-neutral voltages:
  - ☐ phase rotation direction a-b-c: $\vec{V}2 = \frac{1}{3} \times (\vec{V}an + a^2\vec{V}bn + a\vec{V}cn)$
  - ☐ phase rotation direction a-c-b: $\vec{V}2 = \frac{1}{3} \times (\vec{V}an + a\vec{V}bn + a^2\vec{V}cn)$
- or from the two main phase-to-phase voltages:
  - ☐ phase rotation direction a-b-c: $\vec{V}2 = \frac{1}{3} \times (\vec{V}ab - a\vec{V}bc)$
  - ☐ phase rotation direction a-c-b: $\vec{V}2 = \frac{1}{3} \times (\vec{V}ab - a^2\vec{V}bc)$

with $x = e^{j\frac{2\pi}{3}}$

The additional negative sequence voltage **V'2** is calculated the same way:

- from the three additional phase-to-neutral voltages V'an, V'bn, and V'cn
- or from the two additional phase-to-phase voltages V'ab and V'ac

## Readout

Access to the measurements is by one of the following:

- the Sepam™ display via the key
- a PC with SFT2841 software
- a communication link

## Characteristics

| | |
|---|---|
| Measurement Range | 0.05 to 1.2 $V_{Ln}$p **(1)** |
| Units | V or kV |
| Resolution | 1 V |
| Accuracy | ±2 % at $V_{Ln}$p |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1)** VNp: primary rated phase-to-neutral voltage (VNp = $V_{Ln}$p/√3).*

# Frequency

## Operation

Frequency is measured by the following means:

- based on Vab or Van, if only one phase-to-phase voltage connects to Sepam™
- based on positive sequence voltage in other cases

Frequency is *not* measured if:

- the voltage Vab (or Van) or positive sequence voltage **V1** is less than 40% of $V_{LL}$
- the frequency **f** is outside the measurment range

The measurement of the frequency *f'* is calculated according to the same principle, from V'1 or V'ab or V'an.

## Readout

Access to the measurements is by one of the following:

- the Sepam™ display via the ◷ key
- a PC with SFT2841 software
- communication link
- an analog converter with the MSA141 option

## Characteristics

| **Main Channels** | |
|---|---|
| Rated Frequency | 50 Hz, 60 Hz |
| Range | 25 to 65 Hz |
| Resolution | 0.01 Hz (1) |
| Accuracy (2) | ±0.01 Hz |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |
| **Additional Channels** | |
| Rated Frequency fn | 50 Hz, 60 Hz |
| Range | 45 to 55 Hz (fn = 50 Hz) |
| | 55 to 65 Hz (fn = 60 Hz) |
| Resolution (1) | 0.01 Hz |
| Accuracy (2) | ±0.05 Hz |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1)*** *On SFT2841*
***(2)*** *At $V_{LL}p$, under reference conditions (IEC 60255-6)*

# Active, Reactive, and Apparent Power

## Operation

Power values are calculated from the phase currents Ia, Ib and Ic:

- active power = $\sqrt{3}.V_{LL}$p.I. cos $\angle\theta$
- reactive power = $\sqrt{3}.V_{LL}$p.I. sin $\angle$
- apparent power = $\sqrt{3}.V_{LL}$p.I. S

Power calculations can be based on the two or three wattmeter method (see table below), depending on the CTs used.

The two wattmeter method is only accurate when there is no residual current. It is not applicable if the neutral is distributed.

The three wattmeter method gives an accurate calculation of 3-phase and phase by phase powers in all cases whether or not the neutral is distributed.

| Connecting Voltage Channels | Connecting Main Current Channels | P, Q, S, Calculation Method | Power per Phase<br>Pa, Pb, Pc<br>Qa, Qb, Qc<br>Sa, Sb, Sc |
|---|---|---|---|
| 3 V | Ia, Ib, Ic | three wattmeters | Available |
| | Ia, Ic | two wattmeters | Not available |
| Vbc, Vab + Vr | Ia, Ib, Ic | three wattmeters | Available |
| | Ia, Ic | two wattmeters | Not available |
| Vbc, Vab without Vr | Ia, Ib, Ic, or Ia, Ic | two wattmeters | Not available |
| Vab | Ia, Ib, Ic, or Ia, Ic | two wattmeters<br>The system voltage is considered to be balanced | Not available |
| Van | Ia, Ib, Ic, or Ia, Ic | No calculation | Pa, Qa, Sa only |

**Power calculation**

- by three wattmeter method:

$$P = \vec{V}an\vec{I}a\cos(\vec{V}an,\vec{I}a) + \vec{V}bn\vec{I}b\cos(\vec{V}bn,\vec{I}b) + \vec{V}cn\vec{I}c\cos(\vec{V}cn,\vec{I}c)$$

$$Q = \vec{V}an\vec{I}a\sin(\vec{V}an,\vec{I}a) + \vec{V}bn\vec{I}b\sin(\vec{V}bn,\vec{I}b) + \vec{V}cn\vec{I}c\sin(\vec{V}cn,\vec{I}c)$$

- by two wattmeter method:

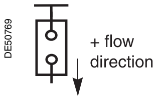
$$P = \vec{V}ab\vec{I}a\cos(\vec{V}ab,\vec{I}a) - \vec{V}bc\vec{I}c\cos(\vec{V}bc\vec{I}c)$$

$$Q = \vec{V}ab\vec{I}a\sin(\vec{V}ab,\vec{I}a) - \vec{V}bc\vec{I}c\sin(\vec{V}bc,\vec{I}c)$$

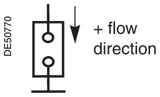
- $S = \sqrt{P^2 + Q^2}$.

According to standard practice:

- for the outgoing circuit (1):
  - ☐ power supplied by the bus is positive
  - ☐ power supplied to the bus is negative



- for the incoming circuit (1):
  - power supplied to the bus is positive
  - power supplied by the bus is negative.



***(1)** Choice made in the general settings*

# Active, Reactive, and Apparent Power

## Readout

Access to the measurements is by one of the following:

- the Sepam™ display via the key
- a PC with SFT2841 software
- communication link
- an analog converter with the MSA141 option

## Characteristics

| | **Active Power**<br>**P, Pa, Pb, Pc** | **Reactive Power**<br>**Q, Qa, Qb, Qc** | **Apparent Power**<br>**S, Sa, Sb, Sc** |
|---|---|---|---|
| Measurement Range | ±(0.8 % Sn at 999 MW) (1) | ±(0.8 % Sn at 999 MVAR) (1) | 0.8 % Sn at 999 MVA (1) |
| Units | kW, MW | kVAR, MVARr | kVA, MVA |
| Resolution | 0.1 kW | 0.1 kvar | 0.1 kVA |
| Accuracy | ±1 % from 0.3 to 1.5 Sn (2)<br>±3 % from 0.1 to 0.3 Sn (2) | ±1 % from 0.3 to 1.5 Sn (3)<br>±3 % from 0.1 to 0.3 Sn (3) | ±1 % from 0.3 to 1.5 Sn<br>±3 % from 0.1 to 0.3 Sn |
| Display Format | 3 significant digits | 3 significant digits | 3 significant digits |
| Refresh Interval | 1 second (typical) | 1 second (typical) | 1 second (typical) |

***(1)*** *Sn =* $\sqrt{3}\,V_{LL}p.I_N$.
***(2)*** *Cos φ > 0.8 under reference conditions (IEC 60255-6)*
***(3)*** *Cos φ < 0.6 under reference conditions (IEC 60255-6)*

# Peak Demand Active and Reactive Power/Power Factor (pf)

## Peak Demand Active and Reactive Power

### Operation

The user determines the regular intervals at which peak demand is calculated for active or reactive power. These intervals generally range from 5 to 60 minutes, during which the current demand amount is calculated and compared with the most recent saved value. The larger of the two values is stored in memory until the next demand interval. The peak value is saved in the event of power loss.

### Readout

Access to the measurements is by one of the following:

- the Sepam™ display via the ◷ key
- a PC with SFT2841 software
- communication link

### Resetting to Zero

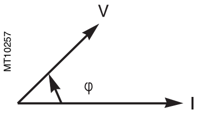
Access to zero reset is by one of the following:

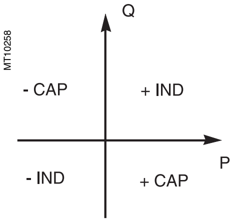
- via the **clear button** on the Sepam™ display if a peak demand is displayed
- via the **clear command** in the SFT2841 software
- via the communication link (remote control command TC5)

### Characteristics

| | Demand Active Power | Demand Reactive Power |
|---|---|---|
| Measurement range | ±(1.5 % Sn at 999 MW) (1) | ±(1.5 % Sn at 999 MVAR) (1) |
| Units | kW, MW | kvar, MVAR |
| Resolution | 0.1 kW | 0.1 kvar |
| Accuracy | ±1 %, typical (2) | ±1 % typical (3) |
| Display format | 3 significant digits | 3 significant digits |
| Integration period | 5, 10, 15, 30, 60 minutes | 5, 10, 15, 30, 60 minutes |

***(1)*** $S_N = \sqrt{3} V_{LL}p.I_N$.
***(2)*** *At* $I_N$, $V_{LL}p$, *cos* $\varphi > 0.8$ *under reference conditions (IEC 60255-6)*
***(3)*** *At* $I_N$, $V_{LL}p$, *cos* $\varphi < 0.6$ *under reference conditions (IEC 60255-6)*





## Power Factor (cos ∠θ)

### Operation

The power factor is defined by: $\mathbf{Pf} = P/\sqrt{P^2 + Q^2}$ . It expresses the phase displacement between the phase currents and phase-to-neutral voltages.

The + and – signs and **IND** (inductive) and **CAP** (capacitive) indications give the direction of power flow and the type of load.

### Readout

Access to the measurements is by one of the following:

- the Sepam™ display via the ◷ key
- a PC with SFT2841 software
- communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | –1 at 1 IND/CAP |
| Resolution | 0.01 |
| Accuracy (1) | 0.01 typical |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1)*** *At* $I_N$, $V_{LL}p$, *pf > 0.8 under reference conditions (IEC 60255-6)*

# Active and Reactive Energy

## Accumulated Active and Reactive Energy

### Operation

Accumulated active and reactive energy values are calculated according to voltages and phase currents Ia, Ib, and Ic, which are derived from measuring the fundamental component . The results of the calculations provide the user with the value of accumulated energy in forward or reverse direction. The accumulated energy values are saved in case of power loss.

### Readout

Access to the measurements is by one of the following:

- the Sepam™ display via the key
- a PC with SFT2841 software
- a communication link.

### Characteristics

| | **Active energy** | **Reactive energy** |
|---|---|---|
| Metering Capacity | 0 to 2.1 $10^8$ MW | 0 to 2.1 $10^8$ MVAR.h |
| Units | MW.h | Mvar.h |
| Resolution | 0.1 MW.h | 0.1 MVAR.h |
| Accuracy | ±1 % typical (1) | ±1 % typical (1) |
| Display Format | 10 significant digits | 10 significant digits |

***(1)** At $I_N$, $V_{LL}p$, pf > 0.8 under reference conditions (IEC 60255-6).*

## Accumulated Active and Reactive Energy by Pulse Metering

### Operation

Use this option to monitor energy from logic inputs. Energy incrementing is associated with each input (one of the general parameters to be set). Each input pulse increments the meter. Four inputs and four accumulated energy metering options are available:

- positive and negative active energy
- positive and negative reactive energy

The accumulated active and reactive energy values are saved if the system loses power.

### Readout

Access to the measurements is by one of the following:

- a PC with SFT2841 software
- a communication link

### Characteristics

| | **Active Energy** | **Reactive Energy** |
|---|---|---|
| Metering Capacity | 0 to 2.1 $10^8$ MW.h | 0 to 2.1 $10^8$ MVAR.h |
| Units | MW.h | MVAR.h |
| Resolution | 0.1 MW.h | 0.1 MVAR.h |
| Display Format | 10 significant digits | 10 significant digits |
| Increment | 0.1 kW.h to 5 MW.h | 0.1 kVAR.h to 5 MVAR.h |
| Pulse | 15 ms min. | 15 ms min. |

# Temperature

## Operation

This function gives the temperature value measured by resistance temperature detectors (RTDs):

- platinum Pt100 (100 Ω at 0 °C or 32 °F) in accordance with IEC 60751 and DIN 43760 standards
- nickel Ni120 (100 Ω or 120 Ω at 0 °C or 32 °F).

Each RTD channel gives one measurement:
tx = RTD x temperature.

The function also indicates RTD faults:

- RTD disconnected (t > 205 °C or t > 401 °F)
- RTD shorted (t < –35 °C or t < –31 °F).

If a fault occurs, display of the value is blocked. The associated monitoring function generates a maintenance alarm.

## Readout

The measurements may be accessed via:

- the Sepam™ display via the key, in °C or °F
- the display of a PC with the SFT2841 software
- communication link
- an analog converter with the MSA141 option

## Characteristics

| | | |
|---|---|---|
| Range | –30 °C to +200 °C | –22 °F to +392 °F |
| Resolution | 1 °C | 1 °F |
| Accuracy | ±1 °C from +20 °C to +140 °C<br>±2 °C from –30 °C to +20 °C<br>±2 °C from +140 °C to +200 °C | ±1.8 °F from +68 °F to +284 °F<br>±3.6 °F from –22 °F to +68 °F<br>±3.6 °F from +284 °F to +392 °F |
| Refresh interval | 5 seconds (typical) | |

### Accuracy Derating According to Wiring

Connection in 3-wire mode: the error **Δt** is directly proportional to the length of the connector and inversely proportional to the connector cross-section:

$$\Delta t(^\circ C) = 2 \times \frac{l(km)}{S(mm^2)}$$

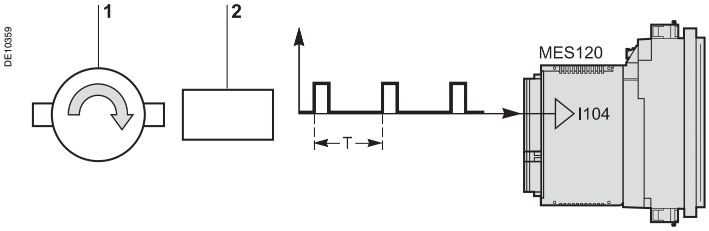
- ±2.1 °C/km for a cross-section of 0.93 mm² (AWG 18)
- ±1 °C/km for a cross-section of 1.92 mm² (AWG 14)

# Rotation Speed

## Operation

Use this function to determine the rotation speed of a motor or generator rotor.

Whenever a rotation is made by the motor or generator shaft, two cams 180 º apart pass a proximity sensor. Each cam generates a pulse that is transmitted by the sensor. The time between the two pulses determines the frequency, or rotation speed of the motor or generator. The number of pulses per rotation is set in the "particular characteristics" screen of the SFT2841 software. The proximity sensor is connected to logic input I104.



**1** Rotor with two cams.
**2** Proximity sensor.

## Readout

The measurements may be accessed via:
- the Sepam™ display via the ⏱ key
- the display of a PC with the SFT2841 software
- the communication link.

## Characteristics

| | | |
|---|---|---|
| Range | | 0 to 7200 rpm |
| Resolution | | 1 rpm |
| Accuracy | | ±1 rpm |
| Refresh Interval | | 1 second (typical) |
| Pulses per Rotation (R) | | 1 to 1800 with $\Omega n\ R/60 \leq 1500$<br>($\Omega n$: rated speed in rpm) |
| Proximity Sensor | Pass-band (in Hz) | $> 2.\omega_N\ R/60$ |
| | Output | 24 to 250 V DC, 3 mA minimum |
| | Leakage current in open status | < 0.5 mA |
| | Voltage dip in closed status | < 4 V (with 24 V DC power supply) |
| | Pulse duration | 0 status > 120 µs |
| | | 1 status > 200 µs |

# Phasor Diagram

## Operation

The phasor diagram displays a vectoral picture of the fundamental component of the raw current and voltage measurements acquired by Sepam™. This enables the user to check cables and implement directional and differential protection functions. The phasor is programmable and the following choices equip the user to adapt the diagram according to requirements:

- measurements displayed in the phasor diagram
- reference phasor
- display mode.

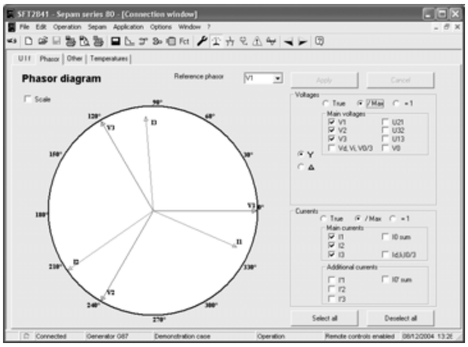
### Measurements to be Displayed

- phase currents on main and additional channel
- residual currents measured or with sum on main and additional channels
- symmetrical components of current I1, I2, IrΣ/3
- phase-to-neutral voltages on main and additional channels
- phase-to-phase voltages on main and additional channels
- residual voltages on main and additional channels
- symmetrical components of voltage V1, V2, Vr/3.

### Reference Phasor

The phasor used as reference is chosen from the phase or residual current or voltage phasors. Phase shifts of the other phasors displayed are calculated according to this reference choice. When the reference phasor is too small (< 2 % IN for currents or 5 % VN for voltages), display is impossible.

PE50453



Reference phasor: V1

☐ Scale

Voltages: ○ True ● / Max ○ = 1

Main voltages: ☑ V1 ☑ V2 ☑ V3 ☐ Vd, Vi, V0/3 ☐ U21 ☐ U32 ☐ U13 ☐ V0

● Y ○ Δ

Currents: ○ True ● / Max ○ = 1

Main currents: ☑ I1 ☑ I2 ☑ I3 ☐ I0 sum ☐ Id,Ii,I0/3

Additional currents: ☐ I'1 ☐ I'2 ☐ I'3 ☐ I0' sum

Connected | Generator G87 | Demonstration case | Operation | Remote controls enabled | 08/12/2004 13:28

*Phasor diagram on SFT2841*

### Display Mode

- **Display as true values.** The measurements are displayed without any modification in a scale chosen in relation to the respective rated values:
  - ☐ 0 to 2 Max (IN, I'N) for currents
  - ☐ 0 to 2 Max ($V_{LL}$p, $V'_{LL}$p) for voltages.
- **Display as values normalized in relation to the maximum.** The measurements are normalized in relation to the greatest measurement of the same type. The greatest measurement is displayed full scale with a modulus equal to 1, and the others are displayed as relative values compared to the modulus 1 value. This display provides maximum angular resolution, regardless of the measured values, while maintaining the relative values between measurements.
- Display as values normalized to 1: all the measurements are normalized in relation to themselves and displayed with a modulus of 1, equal to full scale. This mode provides optimal display of the angles between phasors but does not allow moduli to be compared.
- Displaying phase-to-phase voltage values in a triangle arrangement: for a more common display of phase-to-phase voltage phasors.
- Displaying or eliminating the scale for better reading of displayed phasors.

## Readout

All the possibilities described above can be accessed via the SFT2841 setting and operating software.
Two predefined displays are available on the mimic-based UMI:

- the three phase currents and three phase-to-neutral voltages of the main channels
- the three phase currents of the main channels and the three phase currents of the additional channels

## Characteristics

| Diagram Display Options of an SFT2841 Phasor Diagram | |
|---|---|
| **Measurements to be Displayed** | |
| Multiple selection from: | Ia, Ib, Ic, ir, IrΣ, I1, I2, IrΣ/3, I'a, I'b, I'c, I'r, I'rΣ<br>Van, Vbn, Vcn, Vr, Vab, VbcΣ, Vac, V1, V2, Vr/3<br>V'an, V'bn, V'cn, V'r, V'ab, V'bc, V'ac |
| **Reference Phasor** | |
| Single choice from: | Ia, Ib, Ic, Ir, IrΣ, I'r, I'rΣ<br>Van, Vbn, Vcn, Vr, Vab, Vbc, Vac,<br>V'an, V'bn, V'cn, V'r, V'ab, V'bc, V'ac |
| **Display Mode** | |
| Current display | true (true value)<br>/ max (value normalized in relation to maximum)<br>= 1 (normalized to 1) |
| Voltage display | true (true value)<br>/ max (value normalized in relation to maximum)<br>= 1 (normalized to 1) |
| Phase-to-phase voltage | wye/delta |
| Display of scale | yes/no |

# Network Diagnosis
Tripping Context/Tripping Current

## Tripping Context

### Operation

This function records the values at the time of tripping (activation of the tripping contact on output O1). This allows the user to conduct fault analysis to determine the cause.

The values available from the Sepam™ display are:

- tripping currents
- residual currents Ir, I’r, IrΣ and I’rΣ
- differential and through currents
- phase-to-phase voltages
- residual voltage
- neutral point voltage
- third harmonic neutral point or residual voltage
- frequency
- active power
- reactive power
- apparent power

In addition to these, the following values are available from the SFT2841 software:

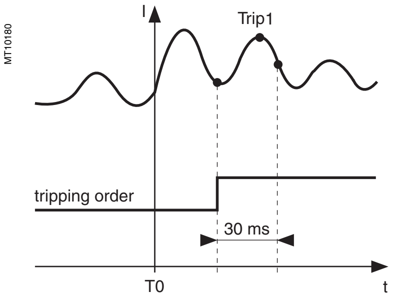
- phase-to-neutral voltages
- negative sequence voltage
- positive sequence voltage

The values for the last five events are saved with the date and time of tripping in case of a power failure. Each new trip value overwrites the oldest event stored in memory.

### Readout

The measurements may be accessed via:

- the Sepam™ display via the icon
- a PC with SFT2841 software loaded
- the communication link



*Tripping current (TripIa) acquisition.*

## Tripping Current

### Operation

This function gives the RMS value of currents at the time of the last trip:

- TripIa: phase a current (main channels)
- TripIb: phase b current (main channels)
- TripIc: phase c current (main channels)
- TripI’a: phase a current (additional channels)
- TripI’b: phase b current (additional channels)
- TripI’c: phase c current (additional channels)

The measurement is defined as the maximum RMS value measured during a 30 ms interval after the activation of the tripping contact on output O1. It is based on measuring the fundamental component.

### Readout

The measurements may be accessed via:

- the Sepam™ display through the icon
- a PC with SFT2841 software loaded
- communication link

### Characteristics

| | |
|---|---|
| Measurement Range | 0.1 to 40 $I_N$ (1) |
| Units | A or kA |
| Resolution | 0.1 A |
| Accuracy | ±5 % ±1 digit |
| Display Format | 3 significant digits |

***(1)** $I_N$, rated current set in the general settings.*

# **Network Diagnosis**
# Number of Phase Fault Trips
# Number of Ground Fault Trips

## Number of Phase Fault Trips

### Operation

This function counts the network phase faults that cause circuit breaker tripping. It counts only trips triggered by protection functions 50/51, 50V/51V, and 67. If there is discrimination between several circuit breakers, the fault is only counted by the Sepam™ that issues the trip command.

Transient faults cleared by the recloser are counted.

The number of phase fault trips is saved in the event of an auxiliary power failure. It can be reinitialized using the SFT2841 software.

### Readout

The measurements may be accessed via:

- the Sepam™ display through the icon
- a PC with SFT2841 software loaded
- the communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 65535 |
| Units | None |
| Resolution | 1 |
| Refresh Interval | 1 second (typical) |

## Number of Ground Fault Trips

### Operation

This function counts the network ground faults that cause circuit breaker tripping. It counts only those trips that are triggered by protection functions 50N/51N and 67N. If there is discrimination between several circuit breakers, the fault is only counted by the Sepam™ that issues the trip command. Transient faults cleared by the recloser are counted.

The number of ground fault trips is saved in the event of an auxiliary power failure. It can be reinitialized using the SFT2841 software.

### Readout

The measurements may be accessed via:

- the Sepam™ display through the icon
- a PC with SFT2841 software loaded
- the communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 65535 |
| Units | None |
| Resolution | 1 |
| RefreshInterval | 1 second (typical) |

# Network Diagnosis
## Negative Sequence/ Current Unbalance

### Operation

This function gives the negative sequence component: **T = I2/IB** or **T' = I'2/I'B**.
The negative sequence current is determined based on the phase currents:

- three phases:
  - ☐ phase rotation direction a-b-c: $\vec{I}2 = \frac{1}{3} \times \left(\vec{I}a + a^2\vec{I}_x b + a\vec{I}c\right)$
  - ☐ phase rotation direction a-c-b: $\vec{I}2 = \frac{1}{3} \times \left(\vec{I}a + a\vec{I}_x b + a^2\vec{I}c\right)$
- two phases:
  - ☐ phase rotation direction a-b-c: $\left|\vec{I}2\right| = \frac{1}{\sqrt{3}} \times \left|\vec{I}a - a^2\vec{I}c\right|$
  - ☐ phase rotation direction a-c-b: $\left|\vec{I}2\right| = \frac{1}{\sqrt{3}} \times \left|\vec{I}a - a\vec{I}c\right|$

with $x = e^{j\frac{2\pi}{3}}$

When there are no ground faults, the formulas for 2-phase currents are equivalent to those for 3-phase currents.

### Readout

The measurements may be accessed via:

- the Sepam™ display via the ◎ icon
- a PC with SFT2841 software loaded
- communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 10 to 500 % |
| Units | % IB or % I'B |
| Resolution | 1 % |
| Accuracy | ±2 % |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

# **Network Diagnosis**
# Current Total Harmonic Distortion
# Voltage Total Harmonic Distortion

## Current Total Harmonic Distortion (Ithd)

### Operation

Current total harmonic distortion is used to assess the quality of the current. It is calculated based on phase Ia, calculating up to the 13th harmonic.

Ithd is calculated over 50 periods using the following formula:

$$\mathbf{Ithd = 100\ \%\ \sqrt{\left(\frac{RMS}{H1}\right)^2 - 1}}$$

with:
**RMS** = RMS value of current Ia up to the 13th harmonic
**H1** = value of the fundamental of current Ia

### Readout

The measurements may be accessed via:

- the Sepam™ display via the icon
- a PC with SFT2841 software loaded
- communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 100 % |
| Units | % |
| Resolution | 0.1 % |
| Accuracy (1) | ±1 % at IN for Ithd > 2 % |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1)** Under reference conditions (IEC 60255-6).*

## Voltage Total Harmonic Distortion (Vthd)

### Operation

Voltage total harmonic distortion is used to assess the quality of the voltage. It is calculated based on the measurement of Vab or Va according to the configuration, calculating for 13th level harmonics.

Vthd is calculated over 50 periods using the following formula:

$$\mathbf{Vthd = 100\ \%\ \sqrt{\left(\frac{RMS}{H1}\right)^2 - 1}}$$

with:
**RMS** = RMS value of voltage Vab or Van up to the 13th harmonic
**H1** = value of the fundamental of voltage Vab or Van

### Readout

The measurements may be accessed via:

- the Sepam™ display via the icon
- a PC with SFT2841 software loaded
- a communication link.

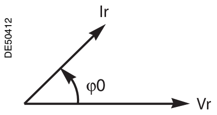
### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 100 % |
| Units | % |
| Resolution | 0.1 % |
| Accuracy (1) | ±1 % at $V_{LL}$N or VN for Vthd > 2 % |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1)** Under reference conditions (IEC 60255-6).*

# Network Diagnosis
Phase Displacement φr, φ'r, φrΣ
Phase Displacement φa, φb, φc

## Phase Displacement φr, φ'r, φrΣ



*Phase displacement φr*

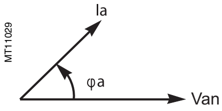
### Operation
This function gives the phase displacement measured between the residual voltage and residual current in the trigonometric (counter-clockwise) direction (see diagram). The measurement is used during commissioning to ensure the directional ground fault protection unit is connected correctly.
Three values are available:
- φr, angle between Vr and measured Ir
- φ'r, angle between Vr and measured I'r
- φrΣ, angle between Vr and IrΣ calculated as the sum of the phase currents.

### Readout
The measurements may be accessed via:
- the Sepam™ display through the icon
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 359° |
| Resolution | 1° |
| Accuracy | ±2° |
| Refresh Interval | 2 seconds (typical) |

## Phase Displacement φa, φb, φc



*Phase displacement φa*

### Operation
This function calculates the phase displacement between the Van, Vbn, Vcn voltages and Ia, Ib, Ic currents respectively, in the trigonometric (counter-clockwise) direction (see diagram). The measurements are used when Sepam™ is commissioned to check voltage and current inputs for correct wiring.

When the phase-to-phase voltages Vab and Vbc are connected to Sepam™ and there is no measurement of residual voltage Vr, the residual voltage is presumed to be zero. The function does not operate when only the voltage Vab or Van is connected to Sepam™.

This function recognizes the convention regarding the direction of energy flow in the outgoing and incoming circuits (see "Power measurements"). Therefore, the angles φa, φb, and φc are adjusted 180° with respect to the values acquired by Sepam™ for the incoming circuits.

### Readout
The measurements may be accessed via:
- the Sepam™ display through the icon
- a PC with SFT2841 software loaded
- communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 359° |
| Resolution | 1° |
| Accuracy | ±2° |
| Refresh Interval | 2 seconds (typical) |

# Network Diagnosis
## Disturbance Recording

## Operation

This function records analog signals and logical states. Record storing is initiated by one or more events set using the SFT2841 software. The stored event begins before the event (based on the pre-trigger programming) and continues afterwards. Recordings comprise the following information:

- values sampled from the different signals
- date
- characteristics of the recorded channels

The naming convention for logic input and output data that Logipam uses is also used in disturbance recording for ease of reading. The duration and number of recordings may be set using the SFT2841 software tool. The files are recorded in First In First Out (FIFO) type shift storage: when the maximum number of recordings is reached, the oldest recording is erased when a new recording is triggered.

### Transfer

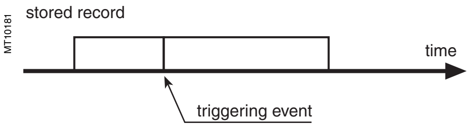
Files will transfer in one of two ways:

- **locally**, by using a PC connected to the front panel and includes the SFT2841 software tool
- **remotely**, by using a software tool specific to the remote monitoring and control system.

### Recovery

The SFT2826 software gives the user the ability to recover a recording.

## Block Diagram



## Characteristics

| | |
|---|---|
| Recording content | Set-up file:<br>date, channel characteristics, measuring chain transformer ratio<br>Sample file:<br>recorded signals |
| Sampling frequency (1) | 12 or 36 samples per network period |
| Analog signals recorded (2) | Ia, Ib, Ic, Ir, I'a, I'b, I'c, I'r current channels<br>Van, Vbn, Vcn, or Vab, Vbc, V'an, V'bn, V'cn, V'ab, V'bc phase voltage channels<br>Vr, VNt or V'r residual voltage channels |
| Logical states recorded (1) (3) | Maximum 32 of the following data:<br>■ all logic inputs / outputs<br>■ pick-up signal<br>■ 1 data item configurable by the logic equation editor or 15 data items configurable by Logipam (V_FLAGREC, V_FLAGREC2 to V_FLAGREC15) |
| Number of recordings stored (1) | 1 to 19 |
| Total duration of a recording (1) | 1 s to 20 s |
| Maximum recording capacity (dist. rec. memory usage = 100 %) | 22 s at 50 Hz, 12 samples per cycle<br>18 s at 60 Hz, 12 samples per cycle<br>7 s at 50 Hz, 36 samples per cycle<br>6 s at 60 Hz, 36 samples per cycle |
| Periods recorded before triggering event (1) | 0 to 99 cycles3 |
| File format | COMTRADE 97 |

***(1)** To be set using the SFT2841 software.*
***(2)** According to type and connection of CTs.*
***(3)** According to Sepam™ hardware configuration.*

# Network Diagnosis
## Sync-Check: Voltage Comparison and Out-of-Sync Context

### Operation

**Voltage Comparison**

For the sync-check function, the MCS025 module continuously measures the amplitude, frequency and phase differences between $V_{LL}$sync1 and $V_{LL}$sync2.

**Out-of-Sync Context**

Out-of-sync context gives a precise indication as to why a synchronization request fails. The context is provided only when the switchgear control function with the "closing with sync-check" option is activated.

When a synchronization request fails, the amplitude, frequency, and phase differences of the $V_{LL}$sync1 and $V_{LL}$sync2 voltages measured by the MCS025 module are recorded, with the date and time, at the end of the switchgear control function "closing request time" delay.

### Readout

The amplitude, frequency and phase differences and out-of-sync context can be accessed via:

- Sepam™ display by using the icon
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| **Amplitude Difference** | |
|---|---|
| Measurement Range | 0 to 120 % of $V_{LL}$sync1 (or $V_{Ln}$sync1) |
| Unit | % of $V_{LL}$sync1 (or $V_{Ln}$sync1) |
| Resolution | 0.1 % |
| Accuracy | ±2 % |
| Refresh Interval | 1 second (typical) |
| **Frequency Difference** | |
| Measurement Range | 0 to 10 Hz |
| Unit | Hz |
| Resolution | 0.01 Hz |
| Accuracy | 0.05 Hz |
| Refresh Interval | 1 second (typical) |
| **Phase Difference** | |
| Measurement Range | 0 to 359° |
| Unit | ° |
| Resolution | 1° |
| Accuracy | ±2° |
| Refresh Interval | 1 second (typical) |

# Machine Operation Assistance
Thermal Capacity Used
Cooling Time Constant

## Thermal Capacity Used

### Operation

**Thermal capacity used** is calculated by the thermal overload protection function for cables, capacitors, or machines. The thermal capacity used is related to the load. The thermal capacity used measurement is given as a percentage of the rated thermal capacity. E is the calculated heat rise, Es is the heat rise setting.

### Saving Thermal Capacity Used Values

The thermal capacity used values are saved in the event Sepam™ loses power. The saved value is used again after the outage.

### Readout

Measurements are accessed via:

- the Sepam™ display through the icon
- a PC with SFT2841 software loaded
- a communication link
- an analog converter with the MSA141 option.

### Resetting to Zero

The thermal capacity used can be reset to zero, after entering a password on:

- a Sepam™ display via the clear key
- a PC with SFT2841 software

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 800 % |
| Units | % |
| Display Format | 3 significant digits |
| Resolution | 1 % |
| Refresh Interval | 1 second (typical) |

## Cooling Time Constant

### Operation

The machine thermal overload protection function (49 RMS machine) uses a cooling time constant (T2) the user can enter according to the data given by the machine manufacturer. It can also be information "learned" by Sepam™.
T2 is estimated under two conditions:

**1** after a heating/cooling sequence:
- heating period detected by ES > 70 %
- followed by a shutdown detected by I < 10 % of $I_B$

**2** when the machine temperature is measured by RTDs connected to MET1482 module number 1:
- RTD 1, 2, or 3 assigned to motor/generator stator temperature measurement
- RTD 1, 3, or 5 assigned to transformer temperature measurement.
  After each new heating/cooling sequence is detected, a new T2 value is estimated and displayed in the related SFT2841 screen. Measurement accuracy may be improved by using RTD 8 to measure the ambient temperature.

The machine thermal overload function has two groups of thermal settings for cases such as natural or forced ventilation or two-speed motors. A time constant is estimated for each group of thermal settings.

### Readout

Measurements are accessed via:

- the Sepam™ display by means of the key
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 5 to 600 min |
| Units | min |
| Resolution | 1 min |
| Accuracy | ±5 % |
| Display Format | 3 significant digits |

# **Machine Operation Assistance**
# Operating Time Before Tripping
# Waiting Time After Tripping

## Remaining Operating Time Before Overload Tripping

### Operation

ANSI code 49RMS requires time for the motor to cool sufficiently before allowing a start attempt. ANSI code 66 is a setting that limits the total number of starts (hot, cold, total starts) per hour.

Thermal capacity used is calculated by using the thermal overload protection function for cables, capacitors or machines. The time depends on the thermal capacity used.

### Readout

The measurements may be accessed via:

- a Sepam™ display via the icon
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 999 min |
| Units | min |
| Display Format | 3 significant digits |
| Resolution | 1 min |
| Refresh Interval | 1 second (typical) |

## Waiting Time After Overload Tripping

### Operation

ANSI code 66 is a setting that limits the total number of starts (hot, cold, total starts) per hour. The thermal capacity used is calculated by the thermal overload protection function for cables, capacitors or machines. The time depends on the thermal capacity used.

### Readout

The measurements may be accessed via:

- a Sepam™ display through the icon
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 999 min |
| Units | min |
| Display Format | 3 significant digits |
| Resolution | 1 min |
| Refresh Interval | 1 second (typical) |

# Machine Operation Assistance
Counter/Starting Current and Starting Time

## Running Hours and Operating Time Counter

The counter gives the total running time the protected device (motor, generator, or transformer) has been operating, that is, whenever a phase current is over 0.1 $I_B$. For capacitor applications, up to four counters are available for the running time of steps (1) to (4). These counters total the time that a capacitor step has been connected to the network (capacitor step switch closed).

The initial counter value can be modified using the SFT2841 software.

The counters are saved in case auxiliary power fails.

### Readout

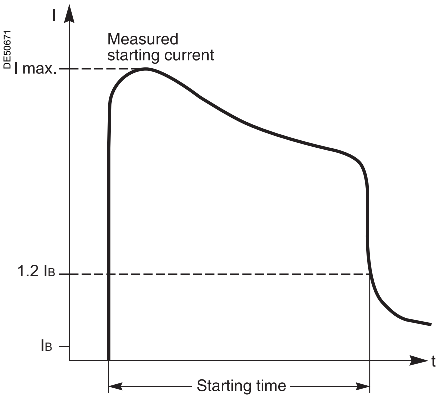
Measurements are accessed via:

- the Sepam™ display via the icon
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Range | 0 to 65535 |
| Units | hours |

## Starting Current and Starting Time



### Operation

The starting time is the time between the moment at which one of the three phase currents exceeds 1.2 $I_B$ and the moment at which the three currents drop back below 1.2 $I_B$. The maximum phase current obtained during this period is the starting current. The two values are saved in case auxiliary power fails.

### Readout

Measurements are accessed via:

- the Sepam™ display via the key
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| **Starting Time** | |
|---|---|
| Measurement Range | 0 to 300 s |
| Units | s or ms |
| Display Format | 3 significant digits |
| Resolution | 10 ms or 1 digit |
| Refresh Interval | 1 second (typical) |
| **Starting Current** | |
| Measurement Range | 1.2 $I_B$ at 24 $I_N$ **(1)** |
| Units | A or kA |
| Display Format | 3 significant digits |
| Resolution | 0.1 A or 1 digit |
| Refresh Interval | 1 second (typical) |

***(1)*** *Or 65.5 kA.*

# **Machine Operation Assistance**
## Number of Starts Before Block/ Start Block Time

## Number of Starts Before Block

### Operation

Blocking is defined as preventing the set number of starts (hot, cold, total starts) from being exceeded. The normally closed (N.C.) contacts of O2 open to prevent starting. The number of starts allowed before block is calculated by the number of starts protection function.

The number of starts depends on the thermal state of the motor.

### Readout

The measurements may be accessed via:

- a Sepam™ display by means of the icon
- a PC with SFT2841 software
- a communication link.

### Resetting to Zero

The number of starts counters may be reset to zero, after entry of a password, on:

- the Sepam™ display via the clear icon
- a PC with SFT2841 software loaded

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 60 |
| Units | None |
| Display Format | 3 significant digits |
| Resolution | 1 |
| Refresh Interval | 1 second (typical) |

## Start Block Time

### Operation

Start block time is calculated by the number of starts protection function. This function indicates that starting is blocked when the allowed number of starts is reached and the circuit breaker is open. The time given represents the waiting time before starting is allowed.

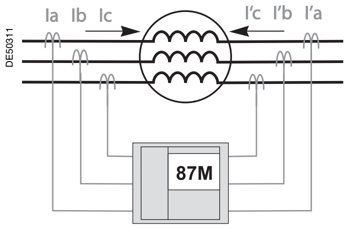
### Readout

The number of starts and waiting time may be accessed via:

- the Sepam™ display via the key
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 360 min |
| Units | min |
| Display Format | 3 significant digits |
| Resolution | 1 min |
| Refresh Interval | 1 second (typical) |



## Differential Current

### Operation

The differential current Id is calculated to facilitate the implementation of the ANSI 87T and ANSI 87M differential protection functions:

- for a rotating machine (ANSI 87M), it is calculated for each phase by:

$$|\vec{I}d| = |\vec{I} + \vec{I'}|$$

- when a transformer is used (ANSI 87T), the Id calculation takes into account the vector shift and transformation ratio:

$$|\vec{I}d| = |\overrightarrow{Irec} + \overrightarrow{I'rec}|$$

The Id value is expressed with respect to IN1, the rated current of the main channels.

### Readout

The measurements may be accessed via:

- the Sepam™ display by using the icon
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0.015 to 40 IN |
| Units | A or kA |
| Resolution | 0.1 A |
| Accuracy (1) | ±5 % |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1)** At IN, under reference conditions (IEC 60255-6).*

## Through Current

### Operation

The through current **It** is calculated to facilitate the implementation of the ANSI 87T and ANSI 87M differential protection functions:

- for a rotating machine (ANSI 87M), it is calculated for each phase by:

$$|\vec{It}| = \left|\frac{\vec{I} - \vec{I'}}{2}\right|$$

- when a transformer is used (ANSI 87T), the It calculation takes into account the vector shift and transformation ratio:

$$|\vec{It}| = \max(|\overrightarrow{Irec}|, |\overrightarrow{I'rec}|)$$

The It value is expressed with respect to In1, the rated current of the main channels.

### Readout

The measurements may be accessed via:

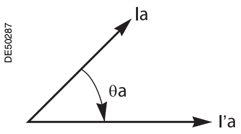
- the Sepam™ display via the icon
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement range | 0.015 to 40 IN |
| Units | A or kA |
| Resolution | 0.1 A |
| Accuracy (1) | ±5 % |
| Display format | 3 significant digits |
| Refresh interval | 1 second (typical) |

***(1)** At IN, under reference conditions (IEC 60255-6).*

# **Machine Operation Assistance**
## Current Phase Displacement



### Operation

Current phase displacement between the main phase currents (I) and additional phase currents (I') (θa, θb, θc) is calculated for each phase.

The measurements are corrected by taking account of the connection and the direction of rotation of the phases to create an image of the vector shift, which must be set in order to use the ANSI 87T differential protection: θr/30 = vector shift (Setting ranges).  This is the protectioin setting range.

### Readout

The measurements may be accessed via:

- the Sepam™ display via the icon
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 359° |
| Units | ° |
| Resolution | 1° |
| Accuracy (1) | ±2° |
| Display Format | 3 significant digits |
| Refresh Interval | 1 second (typical) |

***(1)** At $I_N$, under reference conditions (IEC 60255-6).*

# Machine Operation Assistance
## Apparent Positive Sequence and Phase-to-Phase Impedances

## Apparent Positive Sequence Impedance

### Operation

Apparent positive sequence impedance is used to facilitate the implementation of the underimpedance field loss protection function (ANSI 40).

$$Z1 = \frac{|V1|}{|I1|}$$

### Readout

The measurement may be accessed via:

- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 200 kΩ |
| Units | Ω |
| Resolution | 0.001 Ω |
| Accuracy (1) | ±5 % |
| Refresh Interval | 1 second (typical) |

***(1)** At $I_N$, $V_N$, under reference conditions (IEC 60255-6).*

## Apparent Phase-to-Phase Impedances

### Operation

Apparent phase-to-phase impedances are used to facilitate the implementation of the backup underimpedance protection function (ANSI 21B). They are expressed as the ratio of phase-to-phase voltage to phase-to-phase current.

$$Zab = \frac{|\vec{V}ab|}{|\vec{I}\,ab|} \text{ with } \overrightarrow{Iab} = \vec{I}a - \vec{I}b$$

$$Zbc = \frac{|\vec{V}bc|}{|\vec{I}\,bc|} \text{ with } \overrightarrow{Ibc} = \vec{I}b - \vec{I}c$$

$$Zac = \frac{|\vec{V}ac|}{|\vec{I}\,ac|} \text{ with } \overrightarrow{Iac} = \vec{I}c - \vec{I}a$$

### Readout

The measurement may be accessed via:

- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 200 kΩ |
| Units | Ω |
| Resolution | 0.001 Ω |
| Accuracy (1) | ±5 % |
| Refresh Interval | 1 second (typical) |

***(1)** At $I_N$, $V_N$, under reference conditions (IEC 60255-6).*

## Third Harmonic Neutral Point Voltage

### Operation

Measuring the third harmonic component of the zero sequence voltage occurs at the neutral point of a generator or motor (V0ntH3). The value is used for implementing the third harmonic undervoltage protection function (ANSI 27TN/64G2).

### Readout

The measurements may be accessed via:

- the Sepam™ display via the key
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement range | 0.2 to 30 % of Vnt |
| Units | % of Vnt |
| Resolution | 0.1 % |
| Accuracy (1) | ±1 % |
| Refresh interval | 1 second (typical) |

***(1)*** *Under reference conditions (IEC 60255-6).*

## Third Harmonic Residual Voltage

### Operation

This is a measurement of the third harmonic component of the residual voltage. The residual voltage is calculated by the vectoral sum of the phase-to-neutral voltages.

The value is used for implementing the third harmonic undervoltage protection function (ANSI 27TN/64G2).

### Readout

The measurements may be accessed via:

- the Sepam™ display by using the icon
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0.2 to 90 % of $V_{Ln}$p |
| Units | % fo $V_{Ln}$p |
| Resolution | 0.1 % |
| Accuracy (1) | ±1 % |
| Refresh Interval | 1 second (typical) |

***(1)*** *Under reference conditions (IEC 60255-6).*

# Machine Operation Assistance
## Capacitance

### Operation

This operation provides the user with the total capacitance for each phase of the connected capacitor bank steps. The user can then monitor the condition of the capacitors.

It covers wye and delta connections (a parameter that is set in the "Particular characteristics" screen of the SFT2841 setting and operating software). For this measurement, the installation is considered a perfect capacitance, without considering the resistances added by connecting the capacitor bank steps.

For capacitances measured for wye-connected capacitor bank steps:

- Ca: total capacitance phase a
- Cb: total capacitance phase b
- Cc: total capacitance phase c

For capacitances measured for delta-connected capacitor bank steps:

- Cab: total capacitance between phases a and b
- Cbc: total capacitance between phases b and c
- Cac: total capacitance between phases a and c.

### Readout

The capacitance measurements can be accessed via:

- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 30 F |
| Unit | µF, mF or F |
| Resolution | 0.1 µF |
| Accuracy | ±5 % |
| Refresh Interval | 1 second (typical) |

**Accuracy**

The measurement accuracy is valid if the resistance and inductance per phase of the capacitor bank connecting cable (cable between the Sepam™ CT and the capacitor bank) allow for the following conditions:

- for a wye-connected bank:

$$\mathbf{L}\omega < \mathbf{0.05} \times \left|\frac{\mathbf{1}}{\mathbf{C}\omega}\right|$$

$$\mathbf{R} < \mathbf{0.027} \times \left|\frac{\mathbf{1}}{\mathbf{C}\omega}\right|$$

where **R** is the resistance per phase in ohms (Ω)
**L** is the inductance per phase in Henrys (H)
ω is the angular frequency in radians/s
**C** is the total capacitance per phase in Farads (F)

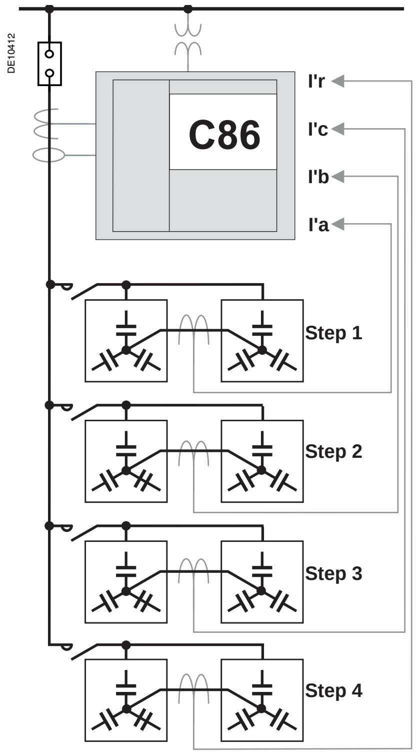
- for a delta-connected bank:

$$\mathbf{L}\omega < \mathbf{0.017} \times \left|\frac{\mathbf{1}}{\mathbf{C}\omega}\right|$$

$$\mathbf{R} < \mathbf{0.009} \times \left|\frac{\mathbf{1}}{\mathbf{C}\omega}\right|$$

where **R** is the resistance per phase in ohms (Ω)
**L** is the inductance per phase in Henrys (H)
ω is the angular frequency in radians/s
**C** is the total capacitance between phases in Farads (F)

# **Machine Operation Assistance**
## Capacitor Unbalance Current



### Operation

This function measures the unbalance current of double wye-connected capacitor bank steps. Unbalanced current is a characteristic of capacitor module damage.

The measurement is carried out via the additional phase and zero sequence current channels:

- I'a: capacitor step 1 unbalance current measurement
- I'b: capacitor step 2 unbalance current measurement
- I'c: capacitor step 3 unbalance current measurement
- I'r: capacitor step 4 unbalance current measurement.

### Readout

The measurements may be accessed through:

- the Sepam™ display key
- a PC with SFT2841 software
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0.02 to 20 $I'_N$ |
| Unit | A |
| Resolution | 0.1 A |
| Accuracy | ±5 % |
| Refresh Interval | 1 second (typical) |

# Switchgear Diagnosis
## VT Supervision
## ANSI Code 60V

### Operation

The Voltage Transformer (VT) supervision function is used to supervise the complete phase and residual voltage measurement chain:

- voltage transformers
- VT connection to Sepam™
- Sepam™ voltage analog inputs.

There are two units for the function, one for supervision of the main voltage channel VTs and the other for supervision of the additional voltage channel VTs.

The function processes the following failures:

- partial loss of phase voltages, detected by:
  - ☐ presence of negative sequence voltage
  - ☐ and absence of negative sequence current
- loss of all phase voltages, detected by:
  - ☐ presence of current on one of the three phases
  - ☐ and absence of all measured voltages
- tripping of the phase VT (and/or residual VT) protection relay, detected by the acquisition on a logic input of the fuse blown contact or auxiliary contact of the circuit breaker protecting the VTs
- other types of failures may be processed using the logic equation editor.

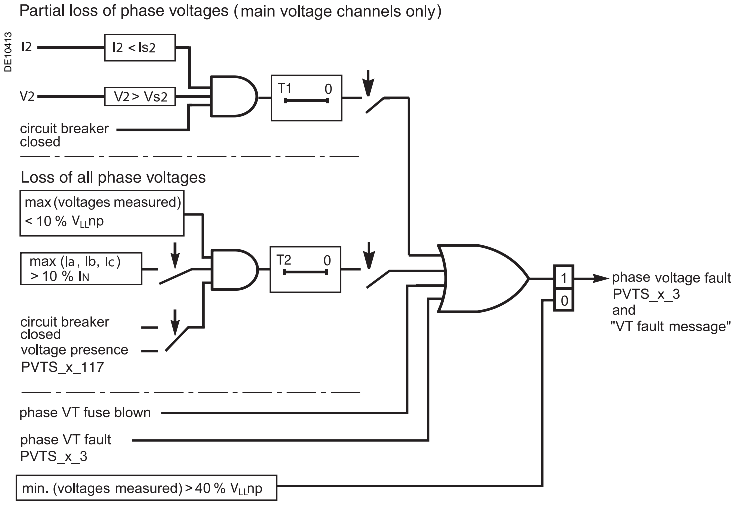
The "Phase voltage fault" and "Residual voltage fault" information disappear automatically when:

- the cause of the fault disappears
- all measured voltages are present.

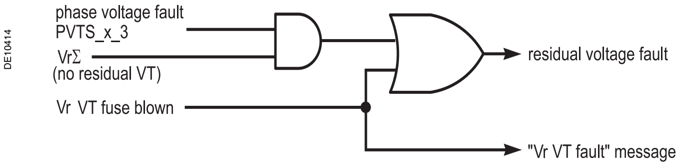
**Using of "Circuit Breaker Closed" Information**
When connected to a logic input, the "circuit breaker closed" information is used to detect the loss of one, two, or three voltages.

In certain applications, the circuit breaker location is insufficient to determine the presence of voltages. In such cases, the equation editor can be used to precisely define the conditions for voltage presence.

### Block Diagram: Phase Voltage Fault Detection.


Partial loss of phase voltages (main voltage channels only)
DE10413
I2
I2 < Is2
V2
V2 > Vs2
circuit breaker closed
T1 0
Loss of all phase voltages
max (voltages measured) < 10 % V_LLnp
max (Ia, Ib, Ic) > 10 % IN
T2 0
circuit breaker closed
voltage presence PVTS_x_117
phase VT fuse blown
phase VT fault PVTS_x_3
min. (voltages measured) > 40 % V_LLnp
1
0
phase voltage fault PVTS_x_3 and "VT fault message"

### Block Diagram: Residual Voltage Fault Detection.


DE10414
phase voltage fault PVTS_x_3
VrΣ (no residual VT)
Vr VT fuse blown
residual voltage fault
"Vr VT fault" message

### Consequences of a VT Fault on Protection Functions

A **Phase voltage fault** affects the following protection functions:

- 21B, 27, 27D, 27TN, 32P, 32Q, 37P, 40, 47, 50/27, 51V, 78PS
- 59, only in cases where the protection function is set up for phase-to-neutral overvoltage, when the voltages are measured by two phase VTs + V0VTs
- 67.

A **residual voltage fault** affects the following protection functions:

- 59N
- 67N/67NC.

The behavior of the protection functions in the event of a "Phase voltage fault" or Residual voltage fault" is to be set up and the following choices are proposed:

- for protection functions 21B, 27, 27D, 27TN, 32P, 32Q, 37P, 40, 47, 50/27, 51V, 59N, 59, 78PS: blocking or no blocking
- for protection function 67: blocking or non-directional operation (50/51)
- for protection function 67N/67NC: blocking or non-directional operation (50N/ 51N).

# Switchgear Diagnosis
## VT Supervision
## ANSI Code 60V

### Setting Advice

The partial loss of voltages is based on detecting the presence of negative sequence voltage and the absence of negative sequence current.

By default:

- the presence of negative sequence voltage is detected when: V2 > 10 % $V_{Ln}$p (Vs2)
- the absence of negative sequence current is detected when: I2 < 5 % IN (Is2)
- time delay T1 is 1 second.

These default settings ensure the stability of the VT supervision function in the event of short-circuits or transient phenomena on the network. The **Is2** set point may be raised for highly unbalanced networks.

Time delay T1 is to be set shorter than the voltage and power protection function tripping times.

Time delay T2 for the detection of the loss of all voltages must be longer than the time it takes for a short-circuit to be cleared by the protection function 50/51 or 67, to avoid the detection of a VT loss of voltage fault triggered by a 3-phase short-circuit.

The time delay for the 51V protection function must be longer than the T1 and T2 time delays used for the detection of voltage losses.

### Characteristics

| **Validating the Detection of Partial Loss of Phase Voltages** | |
|---|---|
| Setting | Yes / No |
| **Vs2 Set Point** | |
| Setting | 10 % to 100 % of $V_{Lnp}$ |
| Accuracy | ±5 % |
| Resolution | 1 % |
| Pick-up / drop-out ratio | 95 % ±2.5 % |
| **Is2 Set Point** | |
| Setting | 5 % to 100 % of IN |
| Accuracy | ±5 % |
| Resolution | 1 % |
| Pick-up / drop-out ratio | 105 % ±2.5 % or > (1 + 0.01 IN/Is2) x 100 % |
| **Time Delay T1 (Partial Loss of Phase Voltages)** | |
| Setting | 0.1 s to 300 s |
| Accuracy | ±2 % or ±25 ms |
| Resolution | 10 ms |
| **Validating the Detection of the Loss of All Phase Voltages** | |
| Setting | Yes / No |
| **Detecting the Loss of All Voltages with Verification of the Presence of Current** | |
| Setting | Yes / No |
| **Voltage Presence Detected by** | |
| Setting | Breaker closed / Logic equation |
| **Time Delay T2 (Loss of All Voltages)** | |
| Setting | 0.1 s to 300 s |
| Accuracy | ±2 % or ±25 ms |
| Resolution | 10 ms |
| **Voltage and Power Protection Behavior** | |
| Setting | No action / block |
| **Protection 67 Behavior** | |
| Setting | Non-directional / block |
| **Protection 67N/67NC Behavior** | |
| Setting | Non-directional / block |

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Phase VT fault | PVTS_x_103 | ■ | ■ |
| Blocking function | PVTS_x_113 | ■ | ■ |
| Voltage presence | PVTS_x_117 | ■ | ■ |

**Outputs**

| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Function output | PVTS_x_3 | ■ | ■ | ■ |
| Function blocked | PVTS_x_16 | ■ | ■ | |

***Note****: x = unit number: x = 1: main channels (V).*
*x = 2: additional channels (V').*

# Switchgear Diagnosis
## CT Supervision
## ANSI Code 60C

### Operation

The Current Transformer (CT) supervision function is used to supervise the complete phase current measurement chain:

- phase CTs (1A / 5A CTs or LPCTs)
- phase current CT connection to Sepam™
- Sepam™ phase current analog inputs

There are two units for the function, one for supervising the main current channel CTs (I) and the other for supervising the additional current channel CTs (I').

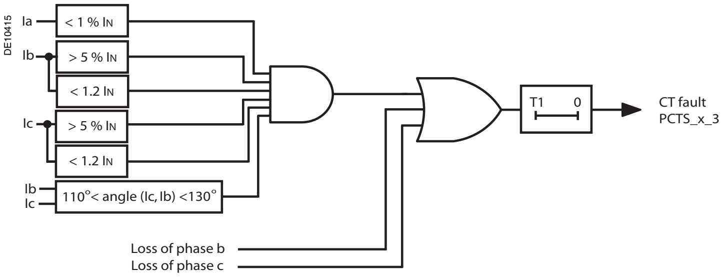
The function is inactive if only two phase CTs are connected.

The "Main CT fault" or "Additional CT fault" information disappears automatically when three phase currents are measured and have values greater than 10 % of IN.

If a phase current is lost, the following protection functions can be blocked to avoid nuisance tripping:

- 21B, 46, 40, 32P, 37P, 32Q, 78PS, 64REF
- 51N and 67N, if Ir is calculated by the sum of the phase currents.

### Block Diagram

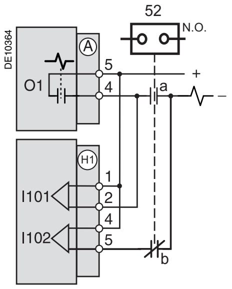


### Characteristics

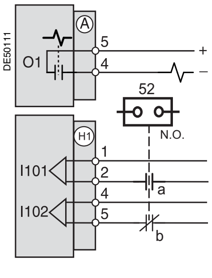
| | | | | |
|---|---|---|---|---|
| **Time Delay** | | | | |
| Setting | | 0.15 s to 300 s | | |
| Accuracy | | ±2 % or ± 25 ms | | |
| Resolution | | 10 ms | | |
| **Blocking Protection Functions 21B, 32P, 32Q, 37P, 40, 46, 51N, 64REF, 67N, 78PS** | | | | |
| Setting | | No action / block | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Block function | PCTS_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Delayed output | PCTS_x_3 | ■ | ■ | ■ |
| Phase a fault | PCTS_x_7 | ■ | ■ | |
| Phase b fault | PCTS_x_8 | ■ | ■ | |
| Phase c fault | PCTS_x_9 | ■ | ■ | |
| Function blocked | PCTS_x_16 | ■ | ■ | |

***Note****: x = unit number: x = 1: main channels (I).*
*x = 2: additional channels (I').*

# Switchgear Diagnosis
## Trip and Closing Circuit Supervision
## ANSI Code 74


DE10364
52
N.O.
A
O1
5
4
+
a
−
H1
I101
1
2
I102
4
5
b

*Connection when trip circuit is wired with NO contacts*


DE50111
A
O1
5
4
+
−
52
H1
N.O.
1
I101
2
4
a
I102
5
b

*Connection when trip circuit is wired with NC contacts*

## Trip Circuit Supervision and Open / Closed Matching

### Operation

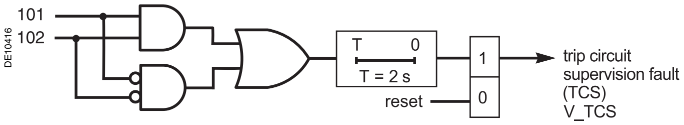
This supervision function operates with trip circuits that use either normally open (NO) or normally closed (NC) trip units. It blocks breaker operation under false conditions.
With NO units, the function detects:

- circuit continuity
- supply loss
- mismatching of position indication contacts

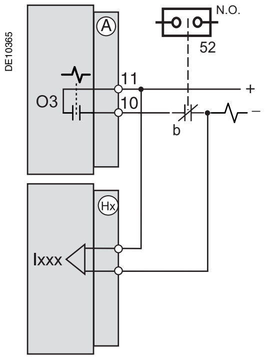
With NC units, the function only detects a mismatch of position indication contacts; it does not check for circuit continuity or supply loss. Trip unit supervision is considered unnecessary in this case.

The information is accessible in the matrix ("trip circuit" message) and by the remote indication TS1.

### Block Diagram


DE10416
101
102
T
0
T = 2 s
reset
1
0
trip circuit supervision fault (TCS)
V_TCS

| Outputs | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Trip circuit supervision fault | V_TCS | | ■ | ■ |


DE10365
N.O.
A
52
O3
11
10
+
b
−
Hx
Ixxx

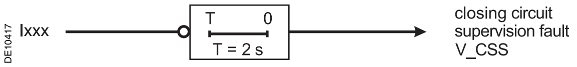
*Connection for closing circuit supervision.*

## Closing Circuit Supervision

### Operation

This function monitors closing coil continuity. It calls for the wiring diagram (opposite), connected to a logic input configured with the "Closing coil supervision" function.
The information is accessible in the matrix ("closing circuit" message) and via remote indication TS234.

### Block Diagram


DE10417
Ixxx
T
0
T = 2 s
closing circuit supervision fault
V_CSS

| Outputs | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Closing circuit supervision fault | V_CCS | | ■ | ■ |

## Open and Close Supervision

### Operation

After an open or close command to a circuit breaker occurs, the system waits 200 milliseconds before checking for compliance. If the circuit breaker status does not match the last command sent, the system generates a "Control fault" message and a remote indication TS2.

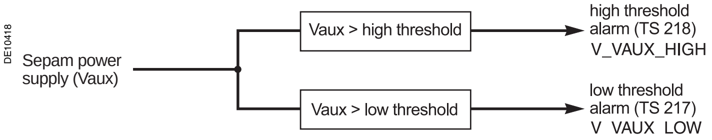
| Outputs | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Control fault<br>(circuit breaker monitoring) | V_CTRLFAUT | | ■ | ■ |

# Switchgear Diagnosis
## Auxiliary Power Supply Monitoring

### Operation

The auxiliary power supply is an important factor in cubicle operation. This function monitors the supply by measuring the Sepam™ power supply voltage and comparing the measured value to low and high thresholds. If the value is outside these limits, an alarm is generated. The related information is available in the matrix and in Logipam.

### Block Diagram


DE10418
Sepam power supply (Vaux)
Vaux > high threshold
Vaux > low threshold
high threshold alarm (TS 218)
V_VAUX_HIGH
low threshold alarm (TS 217)
V VAUX LOW

### Readout

The measurements can be accessed one of the following:

- the Sepam™ display via the icon
- a PC with SFT2841 software
- a communication link.

### Characteristics

| **Measured Auxiliary Voltage Vaux, Low Threshold Alarm, High Threshold Alarm** | |
|---|---|
| Measurement Range | 20 to 275 V DC |
| Units | V |
| Resolution | 0.1 V (1 V on display) |
| Accuracy | ±7 % |
| Refresh Interval | 1 second (typical) |
| **Rated Auxiliary Voltage** | |
| Setting | 24 to 250 V DC |
| Resolution | 1 V |
| **Low Threshold** | |
| Setting | 60 to 95 % of rated V (minimum 20 V) |
| Resolution | 1 V |
| Accuracy | ±7 % |
| **High Threshold** | |
| Setting | 105 to 150 % of rated V (maximum 275 V) |
| Resolution | 1 V |
| Accuracy | ±7 % |

**Outputs**

| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
|---|---|---|---|---|
| Auxiliary power supply monitoring on | V_VAUX_ON | | ■ | |
| High threshold alarm | V_VAUX_HIGH | | ■ | ■ |
| Low threshold alarm | V_VAUX_LOW | | ■ | ■ |

# Switchgear Diagnosis
Cumulative Breaking Current
Number of Operations

## Cumulative Breaking Current Monitoring

### Operation

This function gives the cumulative breaking current in $(kA)^2$ for five current ranges. It is based on measuring the fundamental component on main channels (I).
The current ranges displayed are:

- $0 < I < 2\ I_N$
- $2\ I_N < I < 5\ I_N$
- $5\ I_N < I < 10\ I_N$
- $10\ I_N < I < 40\ I_N$
- $I > 40\ I_N$.

Each value is monitored by an adjustable set point. When the set point is exceeded, an alarm is sent and is available in the matrix and by the remote indication TS235.

These values are saved in the event of an auxiliary power loss. The initial values can be set using the SFT2841 software tool to take into account the actual state of a breaking device used.

The higher number of trips at the higher currents causes more wear on breaker contacts and decreases their life. Refer to switchgear documentation for contact wear specifications.

### Readout

The measurements may be accessed via:

- the Sepam™ display via the icon
- a PC with SFT2841 software
- a communication link.

### Characteristics

| **Cumulative breaking current measured** | |
|---|---|
| Range | 0 to 65535 $(kA)^2$ |
| Units | primary $(kA)^2$ |
| Resolution | $1(kA)^2$ |
| Accuracy (1) | ±10 % ±1 digit |
| **Alarm set point** | |
| Setting | 0 to 65535 $(kA)^2$ |
| Resolution | 1(kA)2 |
| Accuracy (1) | ±10 % ±1 digit |

**Outputs**

| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Cumulative breaking current threshold overrun | V_MAXBRKCUR | | ■ | ■ |

***(1)** At $I_N$, under reference conditions (IEC 60255-6).*

## Number of Operations

### Operation

The function also gives the total number of breaking device operations. It is activated by tripping the 01 contact.

The number of operations is saved in the event of an auxiliary power failure.
It may be reinitialized using the SFT2841 software.

### Readout

The measurements may be accessed via:

- the Sepam™ display via the key
- a PC with the SFT2841 software
- communication link.

### Characteristics

| | |
|---|---|
| Range | 0 to $4.10^9$ |
| Units | None |
| Resolution | 1 |
| Refresh Interval | 1 second (typical) |

# Switchgear Diagnosis
Operating Time/Charging Time

## Operating Time

### Operation

This function gives the value of the opening operating time of a breaking device (1) and change of status of the device open position contact connected to the I102 input (2) The value is saved in the event of an auxiliary power failure.

### Readout

The measurements may be accessed by one of the following:

- a Sepam™ display through the icon
- a PC with SFT2841 software
- communication link.

*(1) Refer to the vendor-provided documentation on the switchgear used for operating time parameter specifications.*

*(2) Optional I/O module.*

### Characteristics

| | |
|---|---|
| Measurement Range | 20 to 100 |
| Units | millisecond (ms) |
| Resolution | 1 ms |
| Accuracy | ±1 ms typical |
| Display Format | 3 significant digits |

## Charging Time

### Operation

This function gives the charge time value of the breaking device (1) operating mechanism. This value is determined by the device closed position status change contact and the end of charging contact connected to the Sepam™ logic inputs (2). The value is saved in the event of an auxiliary power failure.

### Readout

The measurements may be accessed via:

- the Sepam™ display via the key
- the display of a PC with the SFT2841 software
- the communication link.

*(1) Refer to the vendor-provided documentation on the switchgear used for operating time parameter specifications.*

*(2) Optional I/O module.*

### Characteristics

| | |
|---|---|
| Measurement Range | 1 to 20 |
| Units | seconds |
| Resolution | 1 second |
| Accuracy | ±0.5 second |
| Display Format | 3 significant digits |

# Switchgear Diagnosis

## Number of Racking-Out Operations

### Operation

This function keeps a count of circuit breaker or contactor "rackouts", or disconnects. The information can be used for breaking device maintenance. The breaking device's "racked out" or "disconnected" position contacts must be wired to a logic input and set up in the SFT2841 software in order for rackouts to be counted.

The number of disconnects is saved in case auxiliary power fails. It can be reinitialized using the SFT2841 software.

### Readout

The measurements can be accessed by one of the following:

- Sepam™ display via the icon
- a PC with SFT2841 software loaded
- a communication link.

### Characteristics

| | |
|---|---|
| Measurement Range | 0 to 65535 |
| Units | None |
| Resolution | 1 |
| Refresh Interval | 1 second (typical) |

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# Setting Ranges

| Functions | Settings | | Time Delays |
|---|---|---|---|
| **ANSI 12 - Overspeed** | | | |
| | 100 to 160% of Ωn | | 1 to 300 s |
| **ANSI 14 - Underspeed** | | | |
| | 10 to 100% of Ωn | | 1 to 300 s |
| **ANSI 21B - Underimpedance** | | | |
| Impedance Zs | 0.05 to 2.00 $V_N/I_B$ | | |
| **ANSI 24 - Overexcitation (V/Hz)** | | | |
| Tripping curve | Definite time | | |
| | IDMT type A, B or C | | |
| Gs set point | 1.03 to 2 pu | Definite time | 0.1 to 20000 s |
| | | Inverse Definite Minimum Time (IDMT) | 0.1 to 1250 s |
| **ANSI 25 - Sync-Check** | | | |
| Measured voltages | Phase-to-phase | Phase-to-neutral | |
| **Rated Primary Phase-to-Phase Voltage** | | | |
| $V_{L\text{-}Lp}$sync1 ($V_{L\text{-}np}$ sync1 = $V_{L\text{-}Lp}$sync1/$\sqrt{3}$) | 220 V to 250 kV | 220 V to 250 kV | |
| $V_{L\text{-}Lp}$ sync2 ($V_{L\text{-}np}$sync2 = $V_{L\text{-}Lp}$sync2/$\sqrt{3}$) | 220 V to 250 kV | 220 V to 250 kV | |
| **Rated Secondary Phase-to-Phase Voltage** | | | |
| $V_{L\text{-}Ls}$ sync1 | 90 V to 120 V | 90 V to 230 V | |
| $V_{L\text{-}Ls}$ sync2 | 90 V to 120 V | 90 V to 230 V | |
| **Sync-Check Setpoints** | | | |
| dUs set point | 3% to 30% of $V_{LL}$p sync1 | 3% to 30% of $V_{Ln}$p sync1 | |
| dfs set point | 0.05 to 0.5 Hz | 0.05 to 0.5 Hz | |
| dPhi set point | 5 to 80° | 5 to 80° | |
| $V_{LL}$s high set point | 70% to 110% $V_{LL}$p sync1 | 70% to 110% $V_{Ln}$p sync1 | |
| $V_{LL}$s low set point | 10% to 70% $V_{LL}$p sync1 | 10% to 70% $V_{Ln}$p sync1 | |
| **Other Settings** | | | |
| Lead time | 0 to 0.5 s | 0 to 0.5 s | |
| Operating modes: no-voltage conditions for which tie breaking is allowed | Dead1 AND Live2 | Dead1 AND Live2 | |
| | Live1 AND Dead2 | Live1 AND Dead2 | |
| | Dead1 XOR Dead2 | Dead1 XOR Dead2 | |
| | Dead1 OR Dead2 | Dead1 OR Dead2 | |
| | Dead1 AND Dead2 | Dead1 AND Dead2 | |

# Setting Ranges

| Functions | Settings | Time delays |
|---|---|---|
| **ANSI 27 - Undervoltage (L-L) or (L-n)** | | |
| Tripping curve | Definite time | |
| | IDMT | |
| Set point | 5 to 100% of $V_{LL}p$ | 0.05 to 300 s |
| Measurement origin | Main channels (V) or additional channels (V’) | |
| **ANSI 27D - Positive Sequence Undervoltage** | | |
| Set point and time delay | 15 to 60% of $V_{LL}p$ | 0.05 to 300 s |
| Measurement origin | Main channels (V) or additional channels (V’) | |
| **ANSI 27R - Remnant Undervoltage** | | |
| Set point and time delay | 5 to 100% of $V_{LL}p$ | 0.05 to 300 s |
| Measurement origin | Main channels (V) or additional channels (V’) | |
| **ANSI 27TN/64G2 - Third Harmonic Undervoltage** | | |
| Vs set point (fixed) | 0.2 to 20% of Vntp | 0.5 to 300 s |
| K set point (adaptive) | 0.1 to 0.2 | 0.5 to 300 s |
| Positive sequence undervoltage | 50 to 100% of $V_{LL}p$ | |
| Minimum apparent power | 1 to 90% of Sb (Sb = $\sqrt{3}.V_{LL}.I_B$) | |
| **ANSI 32P - Directional Active Overpower** | | |
| | 1 to 120% of Sn (2) | 0.1 s to 300 s |
| **ANSI 32Q - Directional Reactive Overpower** | | |
| | 5 to 120% of Sn (2) | 0.1 s to 300 s |
| **ANSI 37 - Phase Undercurrent** | | |
| | 0.05 to 1 $I_B$ | 0.05 s to 300 s |
| **ANSI 37P - Directional Active Underpower** | | |
| | 5 to 100% of Sn (2) | 0.1 s to 300 s |
| **ANSI 38/49T - Temperature Monitoring** | | |
| Alarm set point TS1 | 0 °C to 180 °C or 32 °F to 356 °F | |
| Trip set point TS2 | 0 °C to 180 °C or 32 °F to 356 °F | |
| **ANSI 40 - Field Loss (Underimpedance)** | | |
| Common point: Xa | 0.02 $V_N/I_B$ to 0.2 $V_{Ln}/I_B$ + 187.5 kΩ | |
| Circle 1: Xb | 0.2 $V_N/I_B$ to 1.4 $V_{Ln}/I_B$ + 187.5 kΩ | 0.05 to 300 s |
| Circle 2: Xc | 0.6 $V_N/I_B$ to 3 $V_{Ln}/I_B$ + 187.5 kΩ | 0.1 to 300 s |

---

***(1)*** *Sn =* $\sqrt{3}$ $I_N.V_{LL}p$

# Setting Ranges

| **Functions** | **Settings** | | **Time delays** | |
|---|---|---|---|---|
| **ANSI 46 - Negative Sequence / Unbalance** | | | | |
| Tripping curve | Definite time | | | |
| | Schneider Electric | | | |
| | IEC: SIT/A, LTI/B, VIT/B, EIT/C | | | |
| | IEEE: MI (D), VI (E), EI (F) | | | |
| | RI$^2$ (setting constant from 1 to 100) | | | |
| Is set point | 0. to 5 IB | Definite time | 0.1 to 300 s | |
| | 0.1 to 0.5 IB (Schneider Electric) | IDMT | 0.1 to 1s | |
| | 0.1 to 1 IB (IEC, IEEE) | | | |
| | 0.03 to 0.2 IB (RI$^2$) | | | |
| Measurement origin | Main channels (I) or additional channels (I’) | | | |
| **ANSI 47 - Negative Sequence Overvoltage** | | | | |
| Set point and time delay | 1 to 50% of $V_{LL}$p | | 0.05 to 300 s | |
| Measurement origin | Main channels (V) or additional channels (V’) | | | |
| **ANSI 48/51LR - Locked Rotor / Excessive Starting Time** | | | | |
| Is set point | 0.5 to 5 IB | ST starting time | 0.5 s to 300 s | |
| | | LT and LTS time delays | 0.05 s to 300 s | |
| **ANSI 49RMS - Thermal Overload for Cables** | | | | |
| Admissible current | 1 to 1.73 IB | | | |
| Time constant T1 | 1 to 600 min | | | |
| **ANSI 49RMS - Thermal Overload for Capacitors** | | | | |
| Alarm current | | 1.05 IB to 1.70 IB | | |
| Trip current | | 1.05 IB to 1.70 IB | | |
| Positioning of the hot tripping curve | Current setting | 1.02 x trip current to 2 IB | | |
| | Time setting | 1 to 2000 minutes (variable range depending on the trip current and current setting) | | |
| **ANSI 49RMS - Thermal Overload for Machines** | | | **Mode 1** | **Mode 2** |
| Accounting for negative sequence component | | 0 - 2.25 - 4.5 - 9 | | |
| Time constant | Heating | | T1: 1 to 600 min | T1: 1 to 600 min |
| | Cooling | | T2: 5 to 600 min | T2: 5 to 600 min |
| Alarm and tripping set points (Es1 and Es2) | | 0 to 300% of rated thermal capacity | | |
| Initial thermal capacity used (Es0) | | 0 to 100% | | |
| Switching of thermal settings condition | | by logic input | | |
| | | by Is set point adjustable from 0.25 to 8 IB | | |
| Maximum equipment temperature | | 140 °F to 392 °F (60 to 200 °C) | | |
| Measurement origin | Main channels (I) or additional channels (I’) | | | |
| **ANSI 50BF - Breaker Failure** | | | | |
| Presence of current | 0.2 to 2 IN | | | |
| Operating time | 0.05 s to 3 s | | | |
| **ANSI 50/27 - Inadvertent Energization** | | | | |
| Is set point | 0.05 to 4 IN | | | |
| Vs set point | 10 to 100% $V_{LL}$p | | T1: 0 to 10 s | |
| | | | T2: 0 to 10 s | |
| **ANSI 50/51 - Phase Overcurrent** | | | | |
| | **Tripping time delay** | **Timer hold** | | |
| Tripping curve | Definite time | DT | | |
| | SIT, LTI, VIT, EIT, UIT (1) | DT | | |
| | RI | DT | | |
| | IEC: SIT/A, LTI/B, VIT/B, EIT/C | DT or IDMT | | |
| | IEEE: MI (D), VI (E), EI (F) | DT or IDMT | | |
| | IAC: I, VI, EI | DT or IDMT | | |
| | Customized | DT | | |
| Is set point | 0.05 to 24 IN | Definite time | Inst; 0.05 s to 300 s | |
| | 0.05 to 2.4 IN | IDMT | 0.1 s to 12.5 s at 10 Is | |
| Timer hold | Definite time (DT; timer hold) | | Inst; 0.05 s to 300 s | |
| | IDMT (IDMT; reset time) | | 0.5 s to 20 s | |
| Measurement origin | Main channels (I) or additional channels (I’) | | | |
| Confirmation | None | | | |
| | By negative sequence overvoltage | | | |
| | By phase-to-phase undervoltage | | | |

***(1)** Tripping as of 1.2 Is.*

# Setting Ranges

| **Functions** | **Settings** | | **Time delays** |
|---|---|---|---|
| **ANSI 50N/51N or 50G/51G - Ground Fault** | | | |
| | **Tripping Time Delay** | **Timer Hold** | |
| Tripping curve | Definite time | DT | |
| | SIT, LTI, VIT, EIT, UIT (1) | DT | |
| | RI | DT | |
| | CEI: SIT/A,LTI/B, VIT/B, EIT/C | DT or IDMT | |
| | IEEE: MI (D), VI (E), EI (F) | DT or IDMT | |
| | IAC: I, VI, EI | DT or IDMT | |
| | EPATR-B, EPATR-C | DT | |
| | Customized | DT | |
| Isr set point | 0.01 to 15 INr (min. 0.1 A) | Definite time | Inst; 0.05 s to 300 s |
| | 0.01 to 1 INr (min. 0.1 A) | IDMT | 0.1 s to 12.5 s at 10 Isr |
| | 0.6 to 5 A | EPATR-B | 0.5 to 1 s |
| | 0.6 to 5 A | EPATR-C | 0.1 to 3 s |
| Timer hold | Definite time (DT; timer hold) | | Inst; 0.05 s to 300 s |
| | IDMT (IDMT; reset time) | | 0.5 s to 20 s |
| Measurement origin | Ir input, I’r input, sum of phase currents IrΣ or sum of phase currents I’rΣ | | |
| **ANSI 50V/51V - Voltage-Restrained Overcurrent** | | | |
| | **Tripping Time Delay** | **Timer Hold** | |
| Tripping curve | Definite time | DT | |
| | SIT, LTI, VIT, EIT, UIT (1) | DT | |
| | RI | DT | |
| | IEC: SIT/A, LTI/B, VIT/B, EIT/C | DT or IDMT | |
| | IEEE: MI (D), VI (E), EI (F) | DT or IDMT | |
| | IAC: I, VI, EI | DT or IDMT | |
| | Customized | DT | |
| Is set point | 0.5 to 24 IN | Definite time | Inst; 0.05 s to 300 s |
| | 0.5 to 2.4 IN | IDMT | 0.1 s to 12.5 s at 10 Is |
| Timer hold | Definite time (DT; timer hold) | | Inst; 0.05 s to 20 s |
| | IDMT (IDMT; reset time) | | 0.5 s to 300 s |
| Measurement origin | Main channels (I) or additional channels (I’) | | |
| **ANSI 51C - Capacitor Bank Unbalance** | | | |
| Is set point | 0.05 A to 2 I’N | Definite time | 0.1 to 300 s |
| **ANSI 59 - Overvoltage (L-L) or (L-N)** | | | |
| Set point and time delay | 50 to 150% of $V_{LL}$p | | 0.05 to 300 s |
| Measurement origin | Main channels (V) or additional channels (V’) | | |
| **ANSI 59N - Neutral Voltage Displacement** | | | |
| Tripping curve | Definite time | | |
| | IDMT | | |
| Set point | 2 to 80% of $V_{LL}$p | Definite time | 0.05 to 300 s |
| | 2 to 10% of $V_{LL}$p | IDMT | 0.1 to 100 s |
| Measurement origin | Main channels (V), additional channels (V’) or neutral-point voltage $V_{Ln}$t | | |
| **ANSI 64REF - Restricted Ground Fault Differential** | | | |
| Isr set point | 0.05 to 0.8 IB (IB ≥ 20 A) | | |
| | 0.1 to 0.8 IB (IB < 20 A) | | |
| Measurement origin | Main channels (I, Ir) or additional channels (I’, I’r) | | |
| **ANSI 66 - Starts per Hour** | | | |
| Total number of starts | 1 to 60 | Period | 1 to 6 h |
| Number of consecutive starts | 1 to 60 | T time delay stop/start | 0 to 90 min |

***(1)*** *Tripping as of 1.2 Is.*

# Setting Ranges

| Functions | | Settings | | Time Delays |
|---|---|---|---|---|
| **ANSI 67 - Directional Phase Overcurrent** | | | | |
| Characteristic angle | | 30°, 45°, 60° | | |
| | | **Tripping Time Delay** | **Timer Hold Delay** | |
| Tripping curve | | Definite time | DT | |
| | | SIT, LTI, VIT, EIT, UIT (1) | DT | |
| | | RI | DT | |
| | | IEC: SIT/A, LTI/B, VIT/B, EIT/C | DT or IDMT | |
| | | IEEE: MI (D), VI (E), EI (F) | DT or IDMT | |
| | | IAC: I, VI, EI | DT or IDMT | |
| | | Customized | DT | |
| Is set point | | 0.1 to 24 IN | Definite time | Inst; 0.05 s to 300 s |
| | | 0.1 to 2.4 IN | IDMT | 0.1 s to 12.5 s at 10 Is |
| Timer hold | | Definite time (DT; timer hold) | | Inst; 0.05 s to 300 s |
| | | IDMT (IDMT; reset time) | | 0.5 s to 20 s |
| **ANSI 67N/67NC Type 1 - Directional Ground Fault, According to Ir Projection** | | | | |
| Characteristic angle | | –45°, 0°, 15°, 30°, 45°, 60°, 90° | | |
| Isr set point | | 0.01 to 15 INr (mini. 0,1 A) | Definite time | Inst; 0.05 s to 300 s |
| Vsr set point | | 2 to 80% of $V_{LL}p$ | | |
| Memory time | | T0mem time | 0; 0.05 s to 300 s | |
| | | Vrmem validity set point | 0; 2 to 80% of $V_{LL}p$ | |
| Measurement origin | | Ir input, I'r input | | |
| **ANSI 67N/67NC Type 2 - Directional Ground Fault, According to Ir Vector Magnitude Directionalized on a Tripping Half-Plane** | | | | |
| Characteristic angle | | -45°, 0°, 15°, 30°, 45°, 60°, 90° | | |
| | | **Tripping Time Delay** | **Timer Hold Delay** | |
| Tripping curve | | Definite time | DT | |
| | | SIT, LTI, VIT, EIT, UIT (1) | DT | |
| | | RI | DT | |
| | | IEC: SIT/A,LTI/B, VIT/B, EIT/C | DT or IDMT | |
| | | IEEE: MI (D), VI (E), EI (F) | DT or IDMT | |
| | | IAC: I, VI, EI | DT or IDMT | |
| | | Customized | DT | |
| Isr set point | | 0.1 to 15 INr (min. 0.1 A) | Definite time | Inst; 0.05 s to 300 s |
| | | 0.01 to 1 INr (min. 0.1 A) | IDMT | 0.1 s to 12.5 s at 10 Isr |
| Vsr set point | | 2 to 80% of $V_{LL}p$ | | |
| Timer hold | | Definite time (DT; timer hold) | | Inst; 0.05 s to 300 s |
| | | IDMT (IDMT; reset time) | | 0.5 s to 20 s |
| Measurement origin | | Ir input, I'r input or sum of phase currents IrΣ | | |
| **ANSI 67N/67NC Type 3 - Directional Ground Fault, According to Ir Vector Magnitude Directionalized on a Tripping Sector** | | | | |
| Tripping sector start angle | | 0° to 359° | | |
| Tripping sector end angle | | 0° to 359° | | |
| Isr set point | CSH zero sequence CT (2A rating) | 0.1 A to 30 A | Definite time | Inst; 0.05 to 300 s |
| | 1A CT | 0.005 to 15 INr (min. 0.1 A) | | |
| | Zero sequence CT + ACE990 (range 1) | 0.01 to 15 INr (min. 0.1 A) | | |
| Vsr set point | | Calculated Vr (sum of 3 voltages) | 2 to 80% of $V_{LL}p$ | |
| | | Measured Vr (external VT) | 0.6 to 80% of $V_{LL}p$ | |
| Measurement origin | | Ir input or I'r input | | |

***(1)** Tripping from 1.2 Is.*

# Setting Ranges

| **Functions** | **Settings** | | **Time Delays** |
|---|---|---|---|
| **ANSI 78PS - Pole Slip** | | | |
| Time delay of the equal-area criterion | 0.1 to 300 s | | |
| Maximum number of power swings | 1 to 30 | | |
| Time between two power swings | 1 to 300 s | | |
| **ANSI 81H - Overfrequency** | | | |
| Set point and time delay | 50 to 55 Hz or 60 to 65 Hz | | 0.1 to 300 s |
| Measurement origin | Main channels (V) or additional channels (V') | | |
| **ANSI 81L - Underfrequency** | | | |
| Set point and time delay | 40 to 50 Hz or 50 to 60 Hz | | 0.1 to 300 s |
| Measurement origin | Main channels (V) or additional channels (V') | | |
| **ANSI 81R - Rate of Change of Frequency** | | | |
| | 0.1 to 10 Hz/s | | 0.15 to 300 s |
| **ANSI 87M - Machine Differential** | | | |
| Ids set point | 0.05 to 0.5 IN (IN ≥ 20 A) | | |
| | 0.1 to 0.5 IN (IN < 20 A) | | |
| **ANSI 87T - Transformer Differential** | | | |
| High set point | 3 to 18 IN1 | | |
| **Percentage-Based Curve** | | | |
| Ids set point | 30 to 100% IN1 | | |
| Slope Id/It | 15 to 50% | | |
| Slope Id/It2 | Without, 50 to 100% | | |
| Slope change point | 1 to 18 IN1 | | |
| **Restraint on Energization** | | | |
| Isinr set point | 1 to 10% | | |
| Delay | 0 to 300 s | | |
| **Restraint on CT Loss** | | | |
| Activity | On / Off | | |
| **Harmonic Restraints** | **Conventional** | **Self-Adaptive** | |
| Selection of restraint | Conventional | Self-adaptive | |
| High set point | On | On / Off | |
| Harmonic 2 percentage set point | Off, 5 to 40% | | |
| Harmonic 2 restraint | Phase-specific/Global | | |
| Harmonic 5 percentage set point | Off, 5 to 40% | | |
| Harmonic 5 restraint | Phase-specific/Global | | |

# Overspeed
## ANSI Code 12

*Detecting excessive machine speeds to protect generators and processes.*

### Description

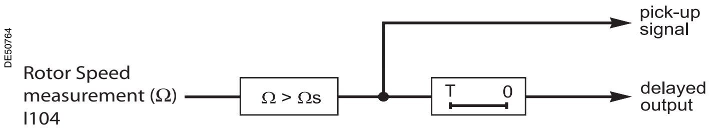
This function detects machine overspeed to identify synchronous generator racing due to loss of synchronism or process monitoring.

Rotation speed is calculated by measuring the time between pulses transmitted by a proximity sensor at each passage of one or more cams driven by the rotation of the motor or generator shaft (see a more in-depth description in the "Metering Functions" chapter of this manual).

The speed acquisition parameters must be set on the "Particular characteristics" screen of the SFT2841 software. The "Rotor speed measurement" function must be assigned to logic input I104 for the function to work.

The protection activates if the measured speed exceeds the speed set point. The protection includes a definite time delay T.

### Block Diagram



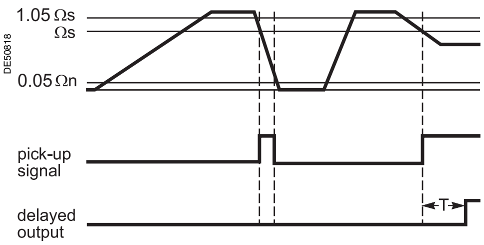
### Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Set Point Ωs** | | | | |
| Setting range | 100 to 160% of Ωn | | | |
| Accuracy [(1)] | ±2% | | | |
| Resolution | 1% | | | |
| Drop out/pick up ratio | 95% | | | |
| **Time Delay T** | | | | |
| Setting range | 1 s to 300 s | | | |
| Accuracy [(1)] | ±25 ms or ±(60000/(Ωs [(2)] x R [(3)])) ms | | | |
| Resolution | 1 s | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P12_x_101 | ■ | ■ | |
| Protection blocking | P12_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P12_x_1 | ■ | ■ | |
| Delayed output | P12_x_3 | ■ | ■ | ■ |
| Protection blocked | P12_x_16 | ■ | ■ | |

*x: unit number.*
*(1) Under reference conditions (IEC 60255-6).*
*(2) Ωs in rpm.*
*(3) R: Number of pulses (cam) per rotation.*

# Underspeed
ANSI Code 14

*Monitoring underspeeds and detecting rotor locking.*



## Description

Rotation speed is calculated by measuring the time between pulses transmitted by a proximity sensor at each passage of one or more cams driven by the rotation of a motor or generator shaft (see a more in-depth description in the "Metering Functions" chapter of this manual).

Monitoring machine speed involves:

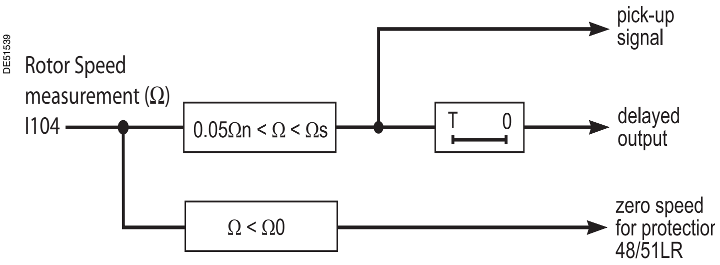
- detecting machine underspeed after starting, for process monitoring, for example
- zero-speed data for detection of locked rotor.

The speed-acquisition and zero-speed detection parameters must be set on the "Particular characteristics" screen of the SFT2841 software.

The "Rotor speed measurement" function must be assigned to logic input I104 for the function to work.

The protection function picks up if the speed measured drops below the speed set point after having first exceeded the set point by 5%. Zero speed is detected by unit 1 and is used by protection function 48/51 LR to detect rotor locking.
The protection includes a definite (DT) time delay T.

## Block Diagram



## Characteristics

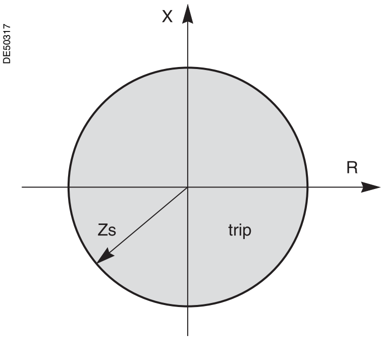
| **Settings** | | | | |
|---|---|---|---|---|
| **Set Point Ωs** | | | | |
| Setting range | 10 to 100% of Ωn | | | |
| Accuracy [(1)] | ±2% | | | |
| Resolution | 1% | | | |
| Drop out/pick up ratio | 105% | | | |
| **Time Delay T** | | | | |
| Setting range | 1 s to 300 s | | | |
| Accuracy [(1)] | ±25 ms or ± (60000/(Ωs [(2)] x R [(3)])) ms | | | |
| Resolution | 1 s with T > (60/(Ωs [(2)] x R [(3)])) | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P14_x_101 | ■ | ■ | |
| Protection blocking | P14_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P14_x_1 | ■ | ■ | |
| Delayed output | P14_x_3 | ■ | ■ | ■ |
| Protection blocked | P14_x_16 | ■ | ■ | |
| Zero speed | P14_x_38 | ■ | ■ | |

*x: unit number.*
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Ωs in rpm.*
***(3)** R: Number of pulses (cam) per rotation.*

# Underimpedance

## ANSI Code 21B

*Phase-to-phase short-circuit protection for generators.*

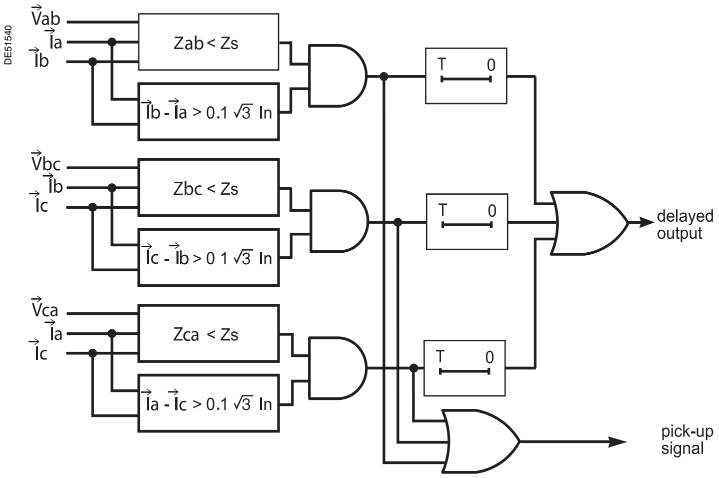


### Description

The protection function is made up of a circular tripping characteristic on the impedance plane (R, X), with a definite time delay. It picks up when one of the apparent, phase-to-phase impedances enters the circular tripping characteristic. The apparent impedances are:

$$\vec{Z}ab = \frac{\vec{V}ab}{\vec{I}a - \vec{I}b}, \quad \vec{Z}bc = \frac{\vec{V}bc}{\vec{I}b - \vec{I}c}, \quad \vec{Z}ac = \frac{\vec{V}ac}{\vec{I}c - \vec{I}a}.$$

### Block Diagram



### Characteristics

| Settings | | | | |
|---|---|---|---|---|
| **Set Point Ωs** | | | | |
| Setting range | $0.05V_N/I_B \le Zs \le 2\ V_N/I_B$ or 0.001 Ω | | | |
| Accuracy (1) | ±2% | | | |
| Resolution | 0.001 Ω or 1 digit | | | |
| Drop out/pick up ratio | 105% | | | |
| **Time Delay T** | | | | |
| Setting range | 200 ms ≤ T ≤ 300 s | | | |
| Accuracy (1) | ±2% or from –10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Characteristic Times (1)** | | | | |
| Operation time | pick-up < 35 ms from infinite to Zs/2 (typically 25 ms) | | | |
| Overshoot time | < 40 ms | | | |
| Reset time | < 50 ms | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P21B_1_101 | ■ | ■ | |
| Protection blocking | P21B_1_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P21B_1_1 | ■ | ■ | |
| Delayed output | P21B_1_3 | ■ | ■ | ■ |
| Protection blocked | P21B_1_16 | ■ | ■ | |

***(1)** Under reference conditions (IEC 60255-6).*

### Example: Synchronous Generator

Synchronous generator data:

- S = 3.15 MVA
- $V_{LL}N1$ = 6.3 kV
- $X_d$ = 233%
- $X'_d$ = 21%

**Protection Setting**

Calculate the rated generator impedance to set the protection function:

- $I_B = S/(\sqrt{3}\ V_{LL}N1) = 289$ A
- $Z_N = V_{LL}N1/(\sqrt{3}\, I_B) = 12.59\ \Omega$.

The tripping parameter is typically set to 30% of the rated generator impedance:

$Zs = 0.30 \times Z_N = 3.77\ \Omega$.

This protection function is used to back up other protection functions. Its setting must ensure discrimination with the other protection functions.
T = 0.9 s, for example, for a network where faults are cleared in 0.6 s.

# Overexcitation (V/Hz)
ANSI Code 24

*Protection of magnetic circuits in transformers and generators*

## Description

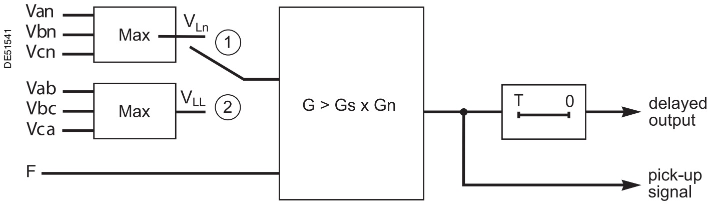
This protection monitors the overexcitation of transformer or generator magnetic circuits by calculating the ratio between the greatest phase-to-neutral or phase-to-phase voltage divided by the frequency.

Overexcitation of magnetic circuits is caused by machine operation with excessive voltage or insufficient frequency. It provokes saturation of the magnetic materials and results in temperature rise. In severe cases, a major flux leakage can occur and seriously damage the materials around the magnetic circuit.

The protection function picks up when the $V_{LL}$/f or $V_{Ln}$/f ratio (depending on VT configuration) exceeds the set point. The function is delayed (definite time (DT) or IDMT) according to three curves (see tripping curve equation on page 173).

The typical tripping set point is 1.05 pu.

## Block Diagram



where G = $V_{LL}$/f or $V_{Ln}$/f depending on VT configuration
Gn = $V_{LL}$n/fn or $V_{Ln}$n/fn depending on the voltage
Gs = the set point

① *phase-to-neutral voltage, see the table below.*

② *phase-to-phase voltage, see the table below.*

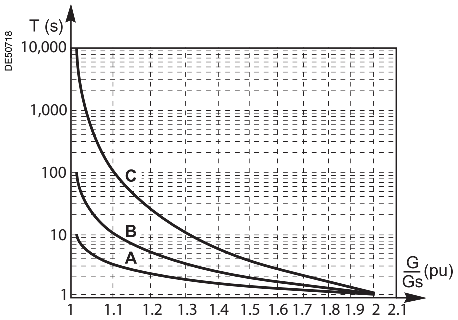
## Voltage Transformer Configuration

This setting adapts the function voltage measurement to the magnetic circuit tie breaker, depending on the measurements made possible by Sepam™ wiring.

| **Voltage Used by the Protection Function** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **VT Wiring** | **3V** | **2$V_{LL}$ + Vr** | **2$V_{LL}$** | **1$V_{LL}$ + Vr** | **1$V_{LL}$** | **1V + Vr** | **1V** |
| Delta | ② | ② | ② | ② | ② | ① | ① |
| Wye | ① | ① | ② | ② | ② | ① | ① |

# Overexcitation (V / Hz)

ANSI Code 24



*Voltage/frequency ratio Inverse Definite Minimum Time (IDMT) tripping curves*

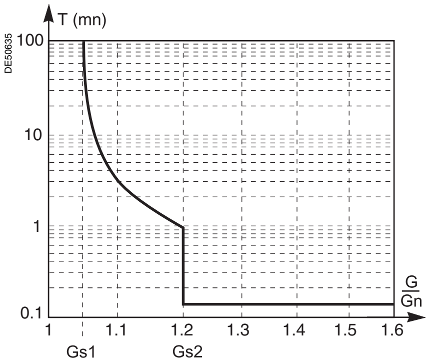
## Characteristics

| | | | | | |
|---|---|---|---|---|---|
| **Settings** | | | | | |
| **VT Configuration** | | | | | |
| Setting range | | Delta / Wye | | | |
| **Tripping Curve** | | | | | |
| Setting range | | Definite time<br>IDMT: type A, type B, type C | | | |
| **Gs Set Point** | | | | | |
| Setting range | | 1.03 to 2.0 pu (2) | | | |
| Accuracy (1) | | ±2% | | | |
| Resolution | | 0.01 pu (2) | | | |
| Drop out/pick up ratio | | 98% ±1% | | | |
| **Time Delay T (Operation Time at 2 pu)** | | | | | |
| Definite time | Setting range | 0.1 to 20000 s | | | |
| | Accuracy (1) | ±2% or from –10 ms to +25 ms | | | |
| IDMT | Setting range | 0.1 to 1250 s | | | |
| | Accuracy (1) | ±2% or from –10 ms to +25 ms | | | |
| Resolution | | 10 ms or 1 digit | | | |
| **Characteristic Times (1)** | | | | | |
| Operation time | | pick-up < 40 ms from 0.9 Gs to 1,1 Gs at fn | | | |
| Overshoot time | | < 40 ms from 0.9 Gs to 1.1 Gs at fn | | | |
| Reset time | | < 50 ms from 1.1 Gs to 0.9 Gs at fn | | | |
| **Inputs** | | | | | |
| **Designation** | | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | | P24_x_101 | ■ | ■ | |
| Protection blocking | | P24_x_113 | ■ | ■ | |
| **Outputs** | | | | | |
| **Designation** | | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | | P24_x_1 | ■ | ■ | |
| Delayed output | | P24_x_3 | ■ | ■ | ■ |
| Protection blocked | | P24_x_16 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

***(2)** 1 pu represents 1 x Gn.*

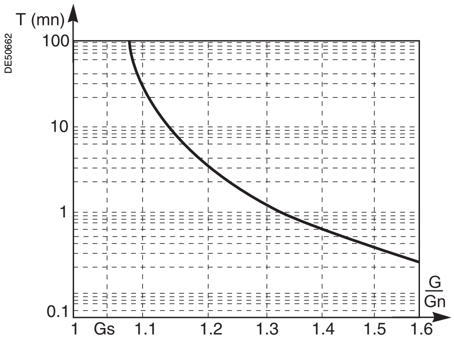


## Example 1. Synchronous Generator

A generator is often protected with two tripping set points:

- an IDMT set point, set to 1.05 Gn with a long delay
  Example: type B curve, Gs1 = 1.05 and T1 = 8 s
- a definite time (DT) set point, set to approximately 1.2 Gn with a tripping time of approximately ten seconds.

For example: DT, Gs2 = 1.2 and T2 = 5 s.



## Example 2. Transformer

A transformer is generally protected by an IDMT set point, set to 1.05 Gn with a long delay

For example: type C curve, Gs = 1.05 and T = 4 s.

# Sync-Check
## ANSI Code 25

*This protection function checks the synchronization of the electrical networks upstream and downstream from a circuit breaker and allows closing when the differences in voltage, frequency or phase are within authorized limits.*

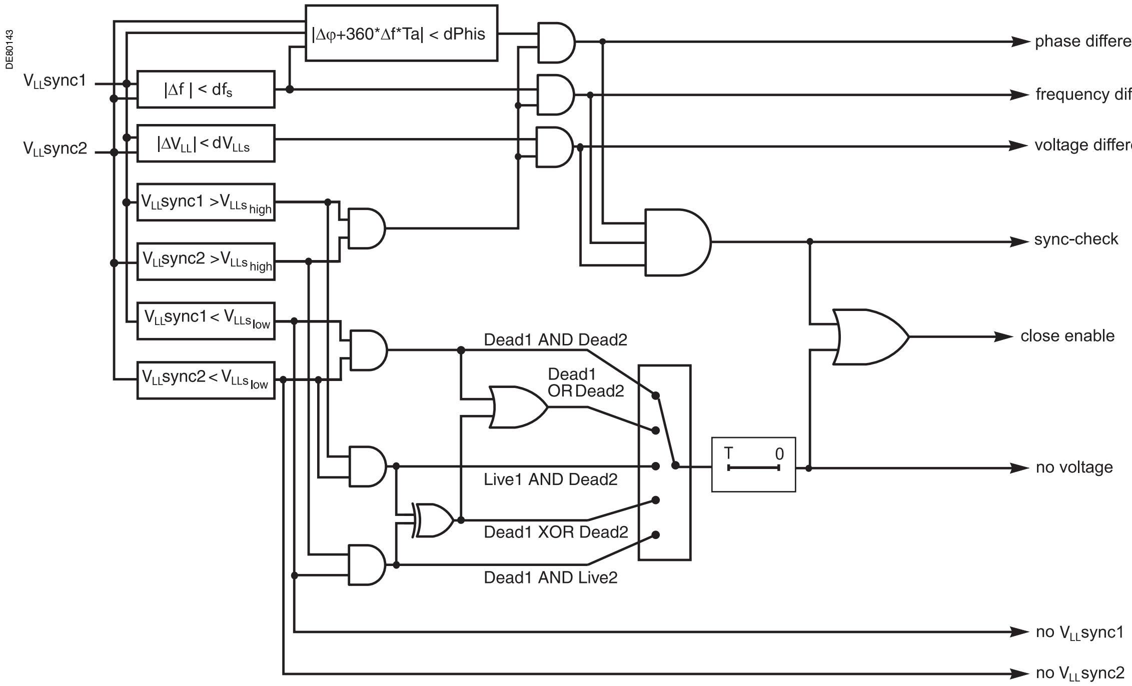
### Operation

The sync-check function is designed to allow circuit breaker closing without any risk of dangerous closing between two voltages $V_{LL}$sync1 and $V_{LL}$sync2. The voltages compared may be two phase-to-phase voltages or two phase-to-neutral voltages ($V_{Ln}$).

The function enables when there is a phase, frequency or amplitude difference (within set limits) between the voltages that are compared.

The function is available in the optional MCS025 module. The "Close enable" logic data must connect to a logic input on the Sepam™. All other data and measurements are transmitted to the Sepam™ base unit through the CCA785 connection cord.

### Block Diagram


DE80143
$V_{LL}$sync1
$V_{LL}$sync2
$|\Delta\varphi+360^*\Delta f^*Ta| < dPhis$
$|\Delta f| < df_s$
$|\Delta V_{LL}| < dV_{LLs}$
$V_{LL}$sync1 >$V_{LLs\,high}$
$V_{LL}$sync2 >$V_{LLs\,high}$
$V_{LL}$sync1 < $V_{LLs\,low}$
$V_{LL}$sync2 < $V_{LLs\,low}$
phase difference
frequency difference
voltage difference
sync-check
close enable
Dead1 AND Dead2
Dead1 OR Dead2
Live1 AND Dead2
Dead1 XOR Dead2
Dead1 AND Live2
T 0
no voltage
no $V_{LL}$sync1
no $V_{LL}$sync2

### Anticipation

It is possible to anticipate the function by a time, Ta, compensating for the frequency difference and the circuit breaker closing time in order to synchronize the voltages at the time of closing.

### Voltage Checking

When one of the two voltages is absent, closing may be authorized according to one of five voltage checking modes.

- $V_{LL}$sync1 absent and $V_{LL}$sync2 present (Dead1 AND Live2)
- $V_{LL}$sync1 present and $V_{LL}$sync2 absent (Live1 AND Dead2)
- One voltage is present and the other is absent (Dead1 XOR Dead2)
- One or both of the two voltages are absent (Dead1 OR Dead2)
- Both voltages are absent (Dead1 AND Dead2).

The presence of each of the voltages is detected by comparing the voltage to the high set point ($V_{LL}$s high set point). The absence of either of the voltages is detected by comparing the voltage to the low set point ($V_{LL}$s low set point).

# Sync-Check
## ANSI Code 25

### User Information

The following measurements are available:
- voltage difference
- frequency difference
- phase difference.

### Characteristics

| **Settings** | |
|---|---|
| **d$V_{LL}$s Set Point** | |
| Setting range | 3% to 30% $V_{LL}$sync1 |
| Accuracy (1) | ±2.5% or 0,003 $V_{LL}$sync1 |
| Resolution | 1% |
| Drop out/pick up ratio | 106% |
| **dfs Set Point** | |
| Setting range | 0.05 Hz to 0.5 Hz |
| Accuracy (1) | ±10 mHz |
| Resolution | 0.01 Hz |
| Drop out/pick up | < 15 mHz |
| **dPhis Set Point** | |
| Setting range | 5° to 50° |
| Accuracy (1) | ±2° |
| Resolution | 1° |
| Drop out/pick up ratio | 120% |
| **$V_{LL}$s High Set Point** | |
| Setting range | 70% to 110% $V_{LL}$sync1 |
| Accuracy (1) | ±1% |
| Resolution | 1% |
| Drop out/pick up ratio | 93% |
| **$V_{LL}$s Low Set Point** | |
| Setting range | 10% to 70% $V_{LL}$sync1 |
| Accuracy (1) | ±1% |
| Resolution | 1% |
| Drop out/pick up ratio | 106% |
| **Anticipating Circuit Breaker Closing Time** | |
| Setting range | 0.1 to 500 s |
| Accuracy (1) | ±2% or ±25 ms |
| Resolution | 10 ms or 1 digit |
| **Voltage Checking** | |
| Setting range | On / Off |
| **Operating Mode with No Voltage** | |
| Setting range | Dead1 AND Live2<br>Live1 AND Dead2<br>Dead1 XOR Dead2<br>Dead1 OR Dead2<br>Dead1 AND Dead2 |

| **Characteristic Times (1)** | |
|---|---|
| Operation time | < 190 ms |
| d$V_{LL}$ operation time | < 120 ms |
| df operation time | < 190 ms |
| dPhi operation time | < 190 ms |
| Reset time | < 50 ms |

**Outputs (1)**

| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
|---|---|---|---|---|
| Close enable | | | | |
| Sync-check | P25_1_46 | ■ | ■ | |
| No voltage | P25_1_47 | ■ | ■ | |
| Phase difference | P25_1_49 | ■ | ■ | |
| Frequency difference | P25_1_50 | ■ | ■ | |
| Voltage difference | P25_1_51 | ■ | ■ | |
| No $V_{LL}$sync1 | P25_1_52 | ■ | ■ | |
| No $V_{LL}$sync2 | P25_1_53 | ■ | ■ | |

***(1)** Under reference conditions (IEC 60255-6).*

# Undervoltage (L-L or L-N)
ANSI Code 27

*Protection against phase-to-neutral or phase-to-phase undervoltages.*

## Description

Undervoltage monitoring protects motors against the negative effects of low system voltages. It also detects abnormally low network voltage in order to trigger automatic load shedding or source transfer:

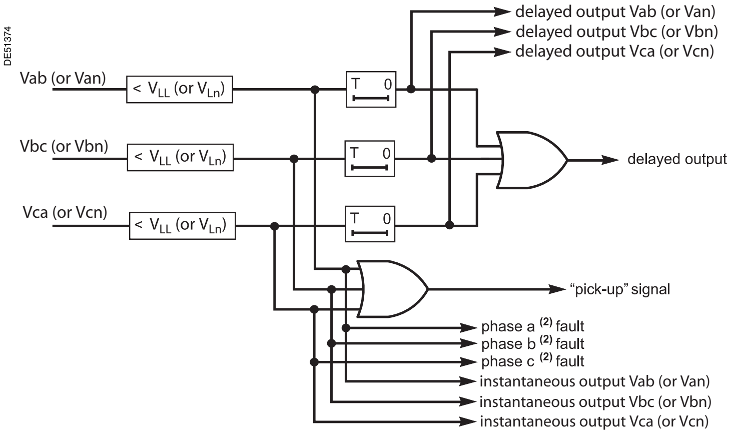
- the protection function is single-phase and operates with phase-to-neutral or phase-to-phase voltage
- it includes a definite (DT) or IDMT time delay T in phase-to-neutral operation (see tripping curve equation on page 173)
- it indicates the faulty phase in the alarm associated with the fault.

Operation with phase-to-neutral or phase-to-phase voltage depends on the connection selected for the voltage inputs.

| **Connection Conditions** | | | |
|---|---|---|---|
| Type of connection | Van, Vbn, Vcn (1) | Vab, Vbc + Vr | Vab, Vbc |
| Phase-to-neutral operation | YES | YES | NO |
| Phase-to-phase operation | YES | YES | YES |
| | | | |
| Type of connection | Vab (1) | Va (1) | |
| Phase-to-neutral operation | NO | On Van only | |
| Phase-to-phase operation | On Vab only | NO | |

*(1) With or without Vr*

## Block Diagram


DE51374
Vab (or Van)
Vbc (or Vbn)
Vca (or Vcn)
< $V_{LL}$ (or $V_{Ln}$)
< $V_{LL}$ (or $V_{Ln}$)
< $V_{LL}$ (or $V_{Ln}$)
T 0
T 0
T 0
delayed output Vab (or Van)
delayed output Vbc (or Vbn)
delayed output Vca (or Vcn)
delayed output
"pick-up" signal
phase a (2) fault
phase b (2) fault
phase c (2) fault
instantaneous output Vab (or Van)
instantaneous output Vbc (or Vbn)
instantaneous output Vca (or Vcn)

## Characteristics

| **Settings** | |
|---|---|
| **Measurement Origin** | |
| Setting range | Main channels ($V_{LL}$) / Additional channels ($V_{LL}$') |
| **Voltage Mode** | |
| Setting range | Phase-to-phase voltage / Phase-to-neutral voltage |
| **Tripping Curve** | |
| Setting range | Definite / IDMT |
| **$V_{LL}$s (or $V_{Ln}$s) Set Point** | |
| Setting range | 5% of $V_{LL}$p (or $V_{Ln}$p) to 100% of $V_{LL}$p (or $V_{Ln}$p) |
| Accuracy (1) | ±2% or ±0.005 $V_{LL}$p |
| Resolution | 1% |
| Drop out/pick up ratio | 103% ±2% |
| **Time Delay T (Tripping Time for Zero Voltage)** | |
| Setting range | 50 ms to 300 s |
| Accuracy (1) | ±2% or ±25 ms |
| Resolution | 10 ms or 1 digit |
| **Characteristic Times** | |
| Operation time | Pick-up < 40 ms from 1.1 $V_{LL}$s ($V_{Ln}$s) to 0.9 $V_{LL}$s ($V_{Ln}$s) (typically 25 ms) |
| Overshoot time | < 40 ms from 1.1 $V_{LL}$s ($V_{Ln}$s) to 0.9 $V_{LL}$s ($V_{Ln}$s) |
| Reset time | < 50 ms from 0.9 $V_{LL}$s ($V_{Ln}$s) to 1.1 $V_{LL}$s ($V_{Ln}$s) |

| **Inputs** | | | |
|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** |
| Protection reset | P27_x_101 | ■ | ■ |
| Protection blocking | P27_x_113 | ■ | ■ |

| **Outputs** | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P27_x_1 | ■ | ■ | |
| Delayed output | P27_x_3 | ■ | ■ | ■ |
| Fault phase a(2) | P27_x_7 | ■ | ■ | |
| Fault phase b (2) | P27_x_8 | ■ | ■ | |
| Fault phase c(2) | P27_x_9 | ■ | ■ | |
| Protection blocked | P27_x_16 | ■ | ■ | |
| Instantaneous output Van or Vab | P27_x_23 | ■ | ■ | |
| Instantaneous output Vbn or Vbc | P27_x_24 | ■ | ■ | |
| Instantaneous output Vcn or Vac | P27_x_25 | ■ | ■ | |
| Delayed output Van or Vab | P27_x_26 | ■ | ■ | |
| Delayed output Vbn or Vbc | P27_x_27 | ■ | ■ | |
| Delayed output Vcn or Vac | P27_x_28 | ■ | ■ | |

*x: unit number.*
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** When the protection function is used for phase-to-neutral voltage.*

# Positive Sequence Undervoltage & Phase Rotation Direction Check
## ANSI Code 27D

*Motor protection against incorrect voltages.*

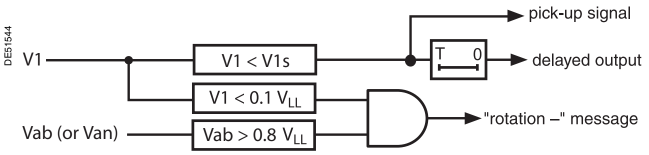
### Description

This feature provides motor protection against faulty operation due to an insufficient or unbalanced network voltage. It is based on measuring the positive sequence voltage V1 and includes a definite time delay T.

It does not operate when only a single phase-to-neutral or phase-to-phase voltage is connected.

This protection also detects the phase rotation direction. The protection function considers that the phase rotation direction is reversed when the positive sequence voltage is less than 10% of $V_{LL}p$ and when the phase-to-phase voltage is greater than 80% of $V_{LL}p$. When this is the case, the alarm message "ROTATION –" is generated.

### Block Diagram



### Characteristics

| | | | | |
|---|---|---|---|---|
| **Settings** | | | | |
| **Measurement Origin** | | | | |
| Setting range | Main channels ($V_{LL}$) / Additional channels ($V_{LL}$') | | | |
| **Vs1 Set Point** | | | | |
| Setting range | 15% $V_{LL}p$ to 60% $V_{LL}p$ | | | |
| Accuracy (1) | ±2% or ±0.005 $V_{LL}p$ | | | |
| Resolution | 1% | | | |
| Drop out/pick up ratio | 103% ±2% | | | |
| **Time Delay T** | | | | |
| Setting range | 50 ms to 300 s | | | |
| Accuracy (1) | ±2% or ±25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Characteristic Times** | | | | |
| Operation time | Pick-up < 40 ms from1.1 Vsd to 0.9 Vsd | | | |
| Overshoot time | < 40 ms from1.1 Vs1 to 0.9 Vs1 | | | |
| Reset time | < 50 ms from 0.9 Vs1 to 1.1 Vs1 | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P27D_x_101 | ■ | ■ | |
| Protection blocking | P27D_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P27D_x_1 | ■ | ■ | |
| Delayed output | P27D_x_3 | ■ | ■ | ■ |
| Protection blocked | P27D_x_16 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

# Remnant Undervoltage
## ANSI Code 27R

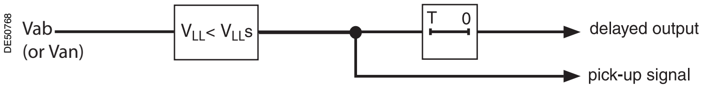
*Detecting the remnant voltage sustained by rotating machines.*

### Description

This protection ensures that the remnant voltage sustained by rotating machines has been cleared before allowing the bus supplying the machines to be re-energized. This is to avoid electrical and mechanical transients.

This is single-phase protection. It enables when the Vab or Van voltage is less than the $V_{LL}$s set point. The protection includes a definite time delay.

### Block Diagram



### Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Measurement Origin** | | | | |
| Setting range | Main channels ($V_{LL}$) / Additional channels ($V_{LL}$') | | | |
| **$V_{LL}$s Set Point** | | | | |
| Setting range | 5% to 100% $V_{LL}$p | | | |
| Accuracy (1) | ±5% or 0.005 $V_{LL}$p | | | |
| Resolution | 1% | | | |
| Drop out/pick up ratio | 103% ±2% | | | |
| **Time Delay T** | | | | |
| Setting range | 50 ms to 300 s | | | |
| Accuracy (1) | ±2% or ±25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Characteristic Times** | | | | |
| Operation time | Pick-up < 45 ms from 1.1 $V_{LL}$s to 0.9 $V_{LL}$s | | | |
| Overshoot time | < 35 ms from 1.1 to 0.9 $V_{LL}$s | | | |
| Reset time | < 35 ms from 0.9 to 1.1 $V_{LL}$s | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P27R_x_101 | ■ | ■ | |
| Protection blocking | P27R_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P27R_x_1 | ■ | ■ | |
| Delayed output | P27R_x_3 | ■ | ■ | ■ |
| Protection blocked | P27R_x_16 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

# Third Harmonic Undervoltage
ANSI Code 27TN/64G2

*Generator protection against insulation faults. This function should be combined with 59N or 51N to ensure 100% stator ground fault protection (64G).*

## Description

This function protects generators against phase-to-ground insulation faults by detecting any reduction of the third harmonic residual voltage.This function protects 10 to 20% of the stator winding on the neutral point end. Complete protection of the stator winding is ensured by combining this function with function 59N or 51N, which protects 85 to 95% of the winding on the terminal end.

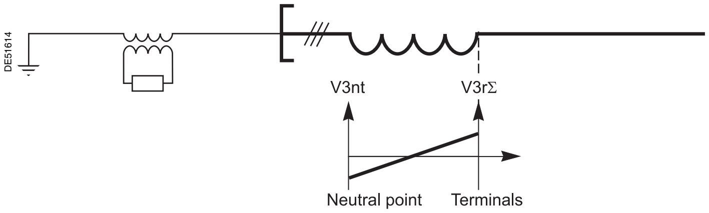
Due to their geometric characteristics, generators produce third-order harmonic voltages (VH3) in addition to the fundamental voltage. The amplitude of the VH3 voltage may vary from 0 to 10% of $V_N$, as a function of:

- network and generator characteristics
- the load on the generator. It is generally higher under full-load than under no-load conditions.

In the absence of a fault, the VH3 voltage must be at least 0.2% of $V_N$ for protection function 27TN.

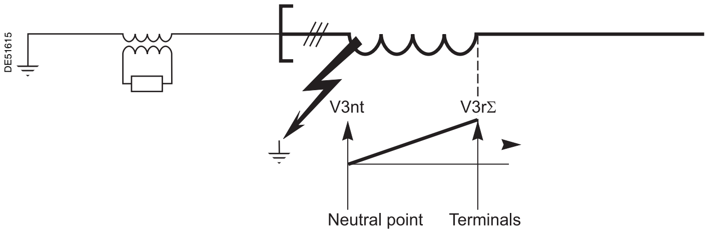
### VH3 Voltage with No Fault

During normal operation, the VH3 voltage is measured at each end of the windings.



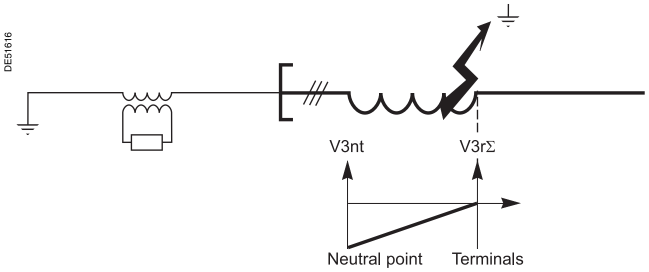
### VH3 Voltage with a Fault on the Neutral Point End

When a single-phase fault occurs in the stator winding near the machine neutral point, the neutral point impedance is short-circuited. This causes a drop in the H3 voltage on the neutral point end.



### VH3 Voltage with a Fault on the Terminal End

When a single-phase fault occurs in the stator winding near the machine terminals, the H3 voltage increases on the neutral point end.



The third harmonic undervoltage protection function detects the drop in the VH3 voltage caused by a single-phase fault on the neutral-point end.

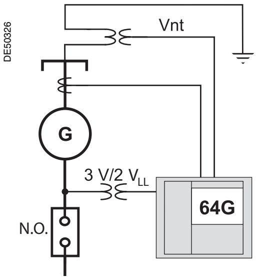
Two types of tripping set points are available according to the VTs connected:

- fixed set point: tripping for VH3 neutral point undervoltage. The setting requires preliminary measurements.
- adaptive set point: tripping for VH3 neutral point undervoltage depending on a set point whose value depends on the VH3 residual voltage. The setting does not require preliminary measurements.

**Availability of Set Points Depending on the VTs Used**

| Voltage Measurements | | Available Types | |
|---|---|---|---|
| **VT Neutral Point** | **VT Terminals** | **27TN Fixed Set Point** | **27TN Adaptive Set Point** |
| - | All wiring | - | - |
| ■ | Van or Vab | - | - |
| ■ | Vab, Vbc | ■ | - |
| ■ | Van, Vbn, Vcn | ■ | ■ |

# Third Harmonic Undervoltage
## ANSI Code 27TN/64G2
## Fixed Set Point



### Operation (Fixed Set Point)

The delayed trip (DT) command is issued if the neutral point VntH3 voltage set point Vcnt is less than the Vs set point.

The protection function operates only if the neutral point VntH3 voltage before the fault is greater than 0.2% of the network phase-to-neutral voltage.

The protection function is blocked if the power (**S**) produced by the generator is low or if the positive sequence voltage (**V1**) is insufficient.

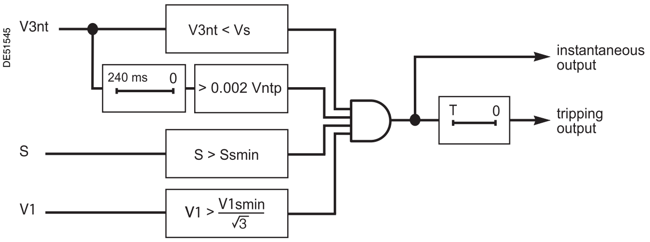
**Adjustment**

This function is adjusted according to a series of measurements on the neutral point VntH3 voltage of the generator. These measurements are used to determine the lowest VntH3 voltage value under normal operating conditions.
The measurements should be carried out:

- under no-load conditions, not connected to the network
- at a number of load levels because the H3 voltage level depends on the load

The parameter is set below the lowest H3 voltage value measured. The Sepam™ unit provides the neutral point VntH3 voltage measurement to facilitate adjustment of the protection function.

### Block Diagram



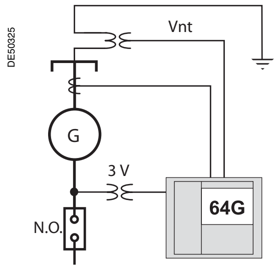
### Characteristics

| | | | | |
|---|---|---|---|---|
| **Settings** | | | | |
| **Type of Set Point** | | | | |
| Setting range | Fixed | | | |
| **Third Harmonic Voltage Set Point Vs** | | | | |
| Setting range | 0.2 to 20% of Vntp | | | |
| Accuracy (1) | ±5% or ±0.05 V of neutral point Vnts | | | |
| Resolution | 0.1% | | | |
| Drop out/pick up ratio | 105% | | | |
| **Time Delay** | | | | |
| Setting range | 0.5 to 300 s | | | |
| Accuracy (1) | ±2% or from –10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Advanced Settings** | | | | |
| **Ssmin Set Point** | | | | |
| Setting range | 1% to 90% of $\sqrt{3}.V_{LL}p.I_B$ | | | |
| Accuracy (1) | ±5% | | | |
| Resolution | 1% | | | |
| Drop out/pick up ratio | 105% | | | |
| **V1smin Positive Sequence Undervoltage Set Point** | | | | |
| Setting range | 50% to 100% of $V_{LL}p$ | | | |
| Accuracy (1) | ±5% | | | |
| Resolution | 1% | | | |
| Drop out/pick up ratio | 105% | | | |
| **Characteristic Times (1)** | | | | |
| Operation time | typically 140 ms from 2 Vs to 0 | | | |
| Overshoot time | < 65 ms | | | |
| Reset time | < 65 ms | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P27TN/64G2_x_101 | ■ | ■ | |
| Protection blocking | P27TN/64G2_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Tripping output | P27TN/64G2_x_3 | ■ | ■ | ■ |
| Protection blocked | P27TN/64G2_x_16 | ■ | ■ | |
| Instantaneous output | P27TN/64G2_x_23 | ■ | ■ | |

*x: unit number.*
***(1)** Under reference conditions (IEC 60255-6).*

# Third Harmonic Undervoltage
ANSI Code 27TN/64G2

Adaptive Set Point



## Operation (Adaptive Set Point)

The H3 voltage (terminal end) VrH3Σ is compared to the H3 voltage VntH3 measured on the neutral point end. The protection function calculates the H3 residual voltage using the three phase-to-neutral voltages. Use of the H3 residual voltage is the means to adapt the tripping set point according to the normal H3 voltage level.
Time-delayed definite time (DT) tripping occurs when:

$$|\mathbf{VntH3}| \;\; y \;\; \frac{\mathbf{K}}{\mathbf{3(1-K)}} \times |\mathbf{VrH3\Sigma}|.$$

The protection function operates only if the neutral point H3 voltage before the fault is greater than 0.2% of the network phase-to-neutral voltage and if the positive sequence voltage is greater than 30% of the phase-to-neutral voltage.

**Adjustment**

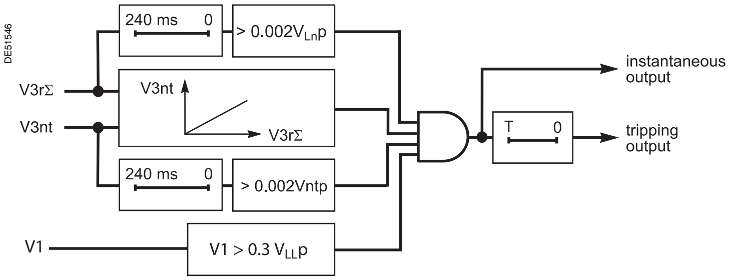
This function does not require any particular measurements but, in certain cases, it may be necessary to adjust the K setting.
The Sepam™ unit measures the neutral point H3 voltage V3nt and the H3 residual voltage VrH3Σ to facilitate adjustment of the protection function.

- V3nt is expressed in % of the primary voltage of the neutral point VT's Vntp
- V3ntΣ is expressed in % of the primary voltage of the terminal-side VT's $V_{Ln}$p.

If the primary voltages of the VTs are different, VntH3 must be adapted to the terminal-side primary voltage Vnp using the equation:

**VntH3 (%$V_{Ln}$p)** = **V3nt (%Vntp)** x $\frac{\mathbf{Vntp}}{\mathbf{VLnp}}$ (See the table on the following page

## Block Diagram



## Characteristics

| | | | | |
|---|---|---|---|---|
| **Settings** | | | | |
| **Type of Set Point** | | | | |
| Setting range | Adaptive | | | |
| **Time Delay** | | | | |
| Setting range | 0.5 to 300 s | | | |
| Accuracy (1) | ±2% or from -10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Advanced Settings** | | | | |
| **K Set Point** | | | | |
| Setting range | 0.1 to 0.2 | | | |
| Accuracy (1) | ±1% | | | |
| Resolution | 0.01 | | | |
| Drop out/pick up ratio | 105% | | | |
| **Characteristic Times (1)** | | | | |
| Operation time | typically 140 ms (2) | | | |
| Overshoot time | < 65 ms | | | |
| Reset time | < 65 ms | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P27TN/64G2_x_101 | ■ | ■ | |
| Protection blocking | P27TN/64G2_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Tripping output | P27TN/64G2_x_3 | ■ | ■ | ■ |
| Protection blocked | P27TN/64G2_x_16 | ■ | ■ | |
| Instantaneous output | P27TN/64G2_x_23 | ■ | ■ | |

*x: unit number.*
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** Measured for a variation of 2V3nt to 0 with VrH3Σ = 30%.*

# Third Harmonic Undervoltage

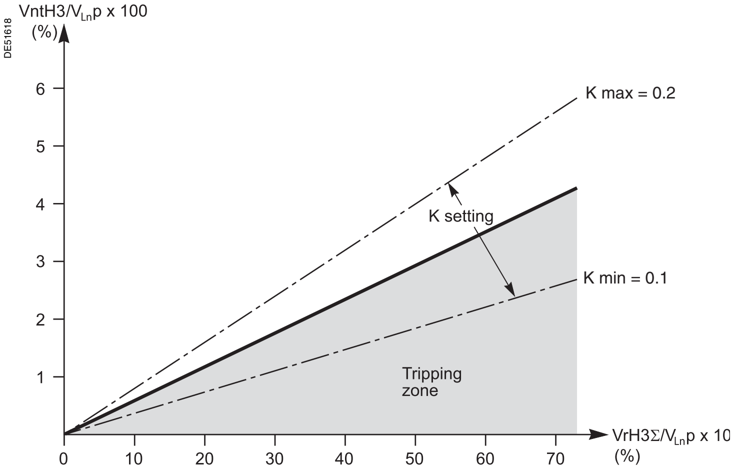
## ANSI Code 27TN/64G2

## Adaptive Set Point

**Curves** $\frac{K}{3(1-K)} \times |V3r\Sigma|$

**Table with Maximum Values of V3nt (%$V_{Ln}$p)**

| K<br>V3rΣ (%$V_{Ln}$p) | 0.10 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.16 | 0.17 | 0.18 | 0.19 | 0.20 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 |
| 2 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.16 | 0.17 |
| 3 | 0.11 | 0.12 | 0.14 | 0.15 | 0.16 | 0.18 | 0.19 | 0.20 | 0.22 | 0.23 | 0.25 |
| 4 | 0.15 | 0.16 | 0.18 | 0.20 | 0.22 | 0.24 | 0.25 | 0.27 | 0.29 | 0.31 | 0.33 |
| 5 | 0.19 | 0.21 | 0.23 | 0.25 | 0.27 | 0.29 | 0.32 | 0.34 | 0.37 | 0.39 | 0.42 |
| 6 | 0.22 | 0.25 | 0.27 | 0.30 | 0.33 | 0.35 | 0.38 | 0.41 | 0.44 | 0.47 | 0.50 |
| 7 | 0.26 | 0.29 | 0.32 | 0.35 | 0.38 | 0.41 | 0.44 | 0.48 | 0.51 | 0.55 | 0.58 |
| 8 | 0.30 | 0.33 | 0.36 | 0.40 | 0.43 | 0.47 | 0.51 | 0.55 | 0.59 | 0.53 | 0.67 |
| 9 | 0.33 | 0.37 | 0.41 | 0.45 | 0.49 | 0.53 | 0.57 | 0.61 | 0.66 | 0.70 | 0.75 |
| 10 | 0.37 | 0.41 | 0.45 | 0.50 | 0.54 | 0.59 | 0.63 | 0.68 | 0.73 | 0.78 | 0.83 |
| 15 | 0.56 | 0.62 | 0.68 | 0.75 | 0.81 | 0.88 | 0.95 | 1.02 | 1.10 | 1.17 | 1.25 |
| 20 | 0.74 | 0.82 | 0.91 | 1.00 | 1.09 | 1.18 | 1.27 | 1.37 | 1.46 | 1.56 | 1.67 |
| 25 | 0.93 | 1.03 | 1.14 | 1.25 | 1.36 | 1.47 | 1.59 | 1.71 | 1.83 | 1.95 | 2.08 |
| 30 | 1.11 | 1.24 | 1.36 | 1.49 | 1.63 | 1.76 | 1.90 | 2.05 | 2.20 | 2.35 | 2.50 |
| 40 | 1.48 | 1.65 | 1.82 | 1.99 | 2.17 | 2.35 | 2.54 | 2.73 | 2.93 | 3.13 | 3.33 |
| 50 | 1.85 | 2.06 | 2.27 | 2.49 | 2.71 | 2.94 | 3.17 | 3.41 | 3.66 | 3.91 | 4.17 |
| 60 | 2.22 | 2.47 | 2.73 | 2.99 | 3.26 | 3.53 | 3.81 | 4.10 | 4.39 | 4.69 | 4.10 |
| 70 | 2.59 | 2.88 | 3.18 | 3.49 | 3.80 | 4.12 | 4.44 | 4.78 | 5.12 | 5.47 | 5.83 |
| 80 | 2.96 | 3.30 | 3.64 | 3.98 | 4.34 | 4.71 | 5.08 | 5.46 | 5.85 | 6.26 | 6.67 |
| 90 | 3.33 | 3.71 | 4.09 | 4.48 | 4.88 | 5.29 | 5.71 | 6.14 | 6.59 | 7.04 | 7.50 |



# Directional Active Overpower

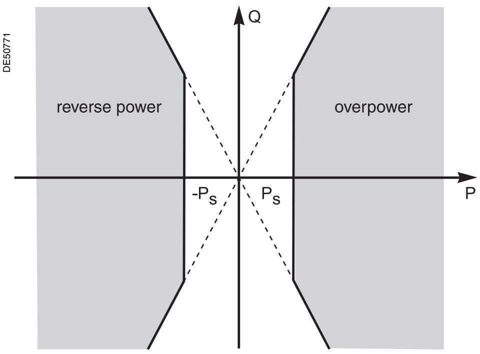
## ANSI Code 32P

*Protection against reverse power and overloads.*

### Description

Two-way protection based on calculated active power, for the following applications:

- active overpower protection to detect overloads and allow load shedding
- reverse active power protection:
  - against generators running like motors when the generators draw active power
  - against motors running like generators when the motors supply active power.



*Operating zone*

This protection function enables if the active power flowing in either direction (supplied or drawn) is greater than set point Ps. It includes a definite time delay, T, and is based on the two or three-wattmeter method of measurement, depending on the connection conditions:

- Van, Vbn, Vcn, and Ia, Ib, Ic: three wattmeters
- Vab, Vbn, Vcn, and Ia, Ic: two wattmeters
- Vab, Vbc with Vr, and Ia, Ib, Ic: three wattmeters
- Vab, Vbc with Vr and Ia, Ic: two wattmeters
- Vab, Vbc without Vr: two wattmeters
- other cases: protection function unavailable.

The function is enabled only if the following condition is met:

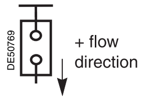
$P \geq 3.1\% \, Q$

This provides a high level of sensitivity and high stability in the event of short-circuits.

The power sign is determined according to the general feeder or main parameter, according to the convention:

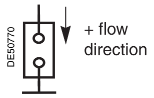
For the feeder circuit:

- power supplied by the bus is positive
- power supplied to the bus is negative

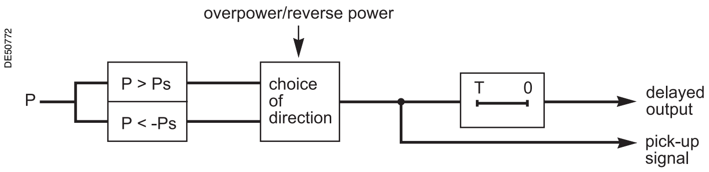


For the Main circuit:

- power supplied to the bus is positive
- power supplied by the busses is negative.



### Block Diagram



### Characteristics

| Settings | | | | |
|---|---|---|---|---|
| **Tripping Direction** | | | | |
| Setting range | Overpower/reverse power | | | |
| **Ps Set Point** | | | | |
| Setting range | 1% of Sn (2) to 120% of Sn (2) | | | |
| Accuracy (1) | ±0.3% Sn for Ps between 1% Sn and 5% Sn<br>±5% for Ps between 5% Sn and 40% Sn<br>±3% for Ps between 40% Sn and 120% Sn | | | |
| Resolution | 0.1 kW | | | |
| Drop out/pick up ratio | 93.5% ±5% or > (1 - 0.004 Sn/Ps) x 100% | | | |
| **Time Delay T** | | | | |
| Setting range | 100 ms to 300 s | | | |
| Accuracy (1) | ±2% or -10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Characteristic Times** | | | | |
| Operation time | < 90 ms at 2 Ps | | | |
| Overshoot time | < 40 ms at 2 Ps | | | |
| Reset time | < 105 ms at 2 Ps | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P32P_x_101 | ■ | ■ | |
| Protection blocking | P32P_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P32P_x_1 | ■ | ■ | |
| Delayed output | P32P_x_3 | ■ | ■ | ■ |
| Protection blocked | P32P_x_16 | ■ | ■ | |
| Positive active power | P32P_x_19 | ■ | ■ | |
| Negative active power | P32P_x_20 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

***(2)** Sn = $\sqrt{3}\, V_{LL}\, I_N$.*

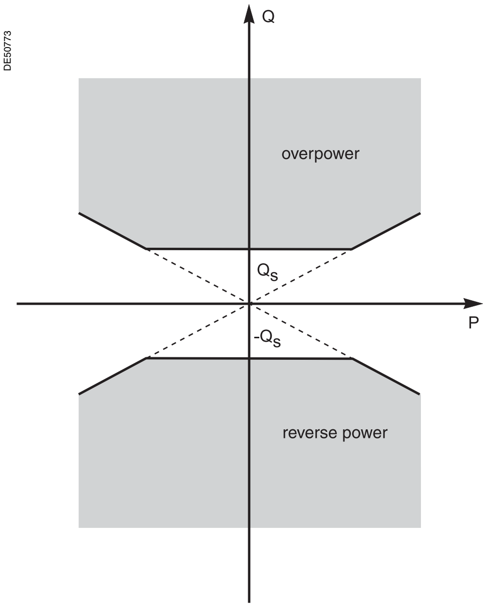
# Directional Reactive Overpower
## ANSI Code 32Q

*Protection against field loss on synchronous machines.*

## Description

This two-way protection is based on calculated reactive power to detect field loss on synchronous machines:

- reactive overpower protection for motors that consume more reactive power following field loss
- reverse reactive overpower protection for generators that consume reactive power following field loss.



*Operating zone.*

The protection function picks up if the reactive power (Q) flowing in one direction or the other (supplied or drawn) is greater than the set point for reactive power.
It includes a definite time delay, T, and is based on the two or three-wattmeter method of measurement, depending on the connection conditions:

- Van, Vbn, Vcn, and Ia, Ib, Ic: three wattmeters
- Van, Vbn, Vcn and Ia, Ic: two wattmeters
- Vab, Vbc with Vr, and Ia, Ib, Ic: three wattmeters
- Vab, Vbc with Vr, and Ia, Ic: two wattmeters
- Vab, Vbc without Vr: two wattmeters
- other cases: protection function unavailable.

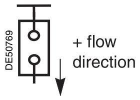
The function is enabled only if the following condition is met:

$Q \geq 3.1\%\ P$

This provides a high level of sensitivity and high stability in the event of short-circuits.
The power sign is determined according to the general feeder or main parameter, according to the convention:

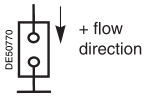
For the feeder circuit:

- power supplied by the busses is positive
- power supplied to the bus is negative

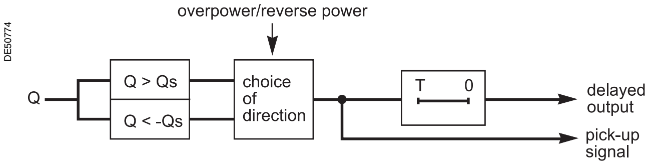


For the Main circuit:

- power supplied to the bus is positive
- power supplied by the busses is negative.



## Block Diagram



## Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Tripping Direction** | | | | |
| Setting range | Overpower/reverse power | | | |
| **Qs Set Point** | | | | |
| Setting range | 5% of Sn (2) to 120% of Sn (2) | | | |
| Accuracy (1) | ±5% for Qs between 5% Sn and 40% Sn<br>±3% for Qs between 40% Sn and 120% Sn | | | |
| Resolution | 0.1 kW | | | |
| Drop out/pick up ratio | 93.5% | | | |
| **Time Delay T** | | | | |
| Setting range | 100 ms to 300 s | | | |
| Accuracy (1) | ±2% or -10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Characteristic Times** | | | | |
| Operation time | < 90 ms | | | |
| Overshoot time | < 95 ms | | | |
| Reset time | < 90 ms | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P32Q_1_101 | ■ | ■ | |
| Protection blocking | P32Q_1_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P32Q_1_1 | ■ | ■ | |
| Delayed output | P32Q_1_3 | ■ | ■ | ■ |
| Protection blocked | P32Q_1_16 | ■ | ■ | |
| Positive reactive power | P32Q_1_54 | ■ | ■ | |
| Negative reactive power | P32Q_1_55 | ■ | ■ | |

***(1)** Under reference conditions (IEC 60255-6).*
***(2)** $Sn = \sqrt{3}\ V_{LL}\ IN$.*

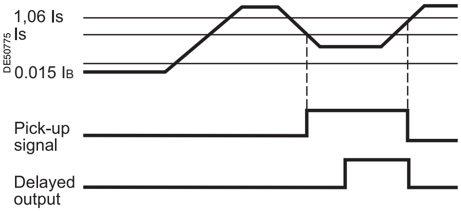
# Phase Undercurrent
ANSI Code 37

*Protection for pumps.*

## Description

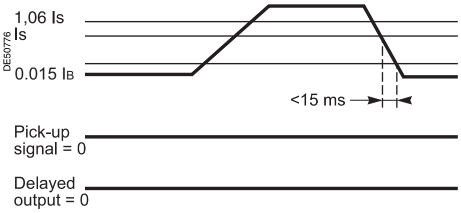
This function protects pumps against the results of a loss of priming by detecting motor no-load operations.

This protection is single-phase. It enables when phase "a" current (Ia) drops below its set point (Is).



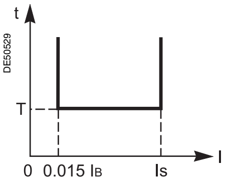
*Current sag.*

This protection is inactive when the current is less than 1.5% of IN. It is insensitive to current drops due to circuit breaker tripping.



*Circuit breaker tripping.*

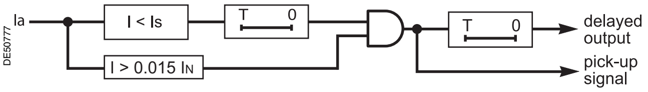
- the protection function includes a definite time delay.



This protection function may be blocked by a logic input.

It can be remotely reset by a remote control command (TC32).

## Block Diagram



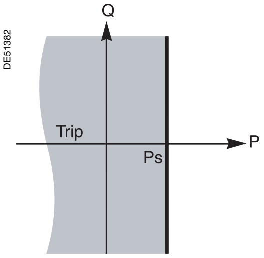
## Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Is Set Point** | | | | |
| Setting range | 5% Ib to 100% IB | | | |
| Accuracy [1] | ±5% | | | |
| Resolution | 1% | | | |
| Drop out/pick up ratio | 106% | | | |
| **Time Delay T** | | | | |
| Setting range | 50 ms to 300 s | | | |
| Accuracy [1] | ±2% or ±25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Characteristic Times** | | | | |
| Operation time | pick-up < 50 ms | | | |
| Overshoot time | < 40 ms | | | |
| Reset time | < 40 ms | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P37_1_101 | ■ | ■ | |
| Protection blocking | P37_1_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P37_1_1 | ■ | ■ | |
| Delayed output | P37_1_3 | ■ | ■ | ■ |
| Protection blocked | P37_1_16 | ■ | ■ | |

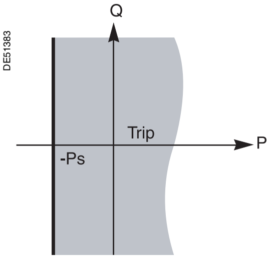
*(1) Under reference conditions (IEC 60255-6).*

# Directional Active Underpower
## ANSI Code 37P

*Check on active power flow.*



*Tripping zone (normal direction).*



*Tripping zone (reverse direction).*

### Description

This two-way protection is based on monitoring the calculated active power flows, for two reasons:

**1** to adapt the number of parallel sources to fit the network load power demand
**2** to create an isolated system in an installation with its own generating unit.

The protection function enables if the active power flowing in one direction or the other (supplied or drawn) is less than the power set point, **Ps**.

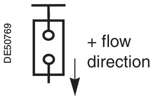
It includes a definite time delay, T,. and is based on the two or three-wattmeter method of measurement, depending on the connection conditions:

- Van, Vbn, Vcn, and Ia, Ib, Ic: three wattmeters
- Van, Vbn, Vcn, and Ia, Ic: two wattmeters
- Vab, Vbc with Vr, and Ia, Ib, Ic: three wattmeters
- Vab, Vbc with Vr, and Ia, Ic: two wattmeters
- Vab, Vbc without Vr: two wattmeters
- other cases: protection function unavailable.

The power sign is determined according to the general feeder or Main parameter, according to the convention:

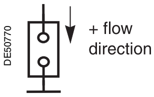
For the feeder circuit:

- power supplied by the bus is positive (normal direction)
- power supplied to the bus is negative

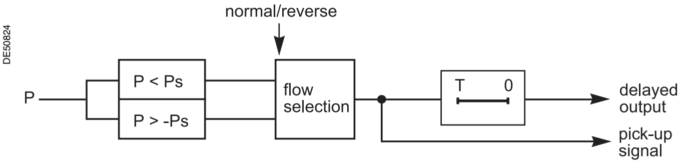


For the main circuit:

- power supplied to the bus is positive (normal direction)
- power supplied by the bus is negative.



### Block Diagram



### Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Tripping Direction** | | | | |
| Setting range | Normal / reverse | | | |
| **Ps Set Point** | | | | |
| Setting range | 5% of Sn (2) to 100% of Sn (2) | | | |
| Accuracy (1) | ±5% for Ps between 5% Sn and 40% Sn<br>±3% for Ps between 40% Sn and 120% Sn | | | |
| Resolution | 0.1 kW | | | |
| Drop out/pick up ratio | 106% | | | |
| **Time Delay T** | | | | |
| Setting range | 100 ms to 300 s | | | |
| Accuracy (1) | ±2% or -10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Characteristic Times** | | | | |
| Operation time | < 120 ms | | | |
| Overshoot time | < 65 ms | | | |
| Reset time | < 60 ms | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P37P_x_101 | ■ | ■ | |
| Protection blocking | P37P_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P37P_x_1 | ■ | ■ | |
| Delayed output | P37P_x_3 | ■ | ■ | ■ |
| Protection blocked | P37P_x_16 | ■ | ■ | |

*x: unit number.*
***(1)** Under reference conditions (IEC 60255-6).*
***(2)** $Sn = \sqrt{3}.V_{LL}\,In$.*

# Temperature Monitoring
ANSI Code 38/49T

*Protection against heat rise in equipment by measuring the temperature with a sensor.*

## Description

This protection detects abnormal heat rise by measuring the temperature inside equipment fitted with sensors:

- transformer: protection of primary and secondary windings
- motor and generator: protection of stator windings and bearings.

This protection function is associated with a Resistance Temperature Detector (RTD), type Pt100 platinum (100 Ω at 0° C or 32° F) or nickel (Ni100 or Ni120), conforming to IEC 60751 and DIN 43760 standards. It activates when the monitored temperature is greater than the temperature set point, Ts. It has two independent set points:

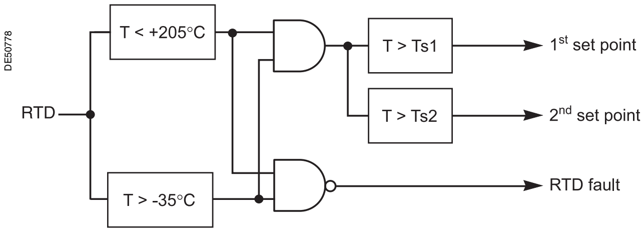
- alarm set point
- tripping set point

When the protection function is activated, it detects whether the RTD is shorted or disconnected:

- **RTD shorting** is detected if the measured temperature is less than –31 °F or –35 °C (measurement displayed "****")
- **RTD disconnection** is detected if the measured temperature is greater than +205 °C or +401 °F (measurement displayed "-****").

If an RTD fault is detected, the protection function is blocked and its output relays are set to zero. The "RTD fault" item is also made available in the control matrix and an alarm message is generated specifying the number of the MET1482 module for the faulty RTD.

## Block Diagram



## Characteristics

| **Settings** | | |
|---|---|---|
| **Alarm and Trip Set Points TS1, TS2** | | |
| Setting range | 0°C to 180°C | 32°F to 356°F |
| Accuracy (1) | ±1.5°C | ±2.7°F |
| Resolution | 1°C | 1°F |
| Pick up / drop out difference | 3°C | 5.4°F |

| **Inputs** | | | |
|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** |
| Protection reset | P38/49T_x_101 | ■ | ■ |
| Protection blocking | P38/49T_x_113 | ■ | ■ |

| **Outputs** | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Protection output | P38/49T_x_3 | ■ | ■ | ■ |
| Alarm | P38/49T_x_10 | ■ | ■ | ■ |
| RTD fault | P38/49T_x_12 | ■ | ■ | |
| Protection blocked | P38/49T_x_16 | ■ | ■ | |

*x: unit number.*
***(1)*** *Under reference conditions (IEC 60255-6).*

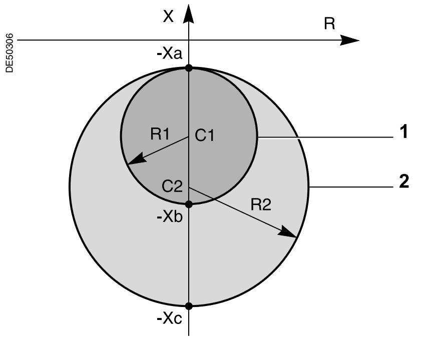
# Loss of Field
## ANSI Code 40

*Protection against loss of field on synchronous motors or generators.*

## Description

The protection function is made up of two circular tripping characteristics on the impedance plane (R, X). It enables when the positive sequence impedance Z1 enters one of the circular tripping characteristics.

$$\vec{Z}1 = \frac{\vec{V}1}{\vec{I}1}$$


DE50306
X
R
-Xa
R1
C1
1
C2
2
R2
-Xb
-Xc

**Circular Tripping Characteristics**

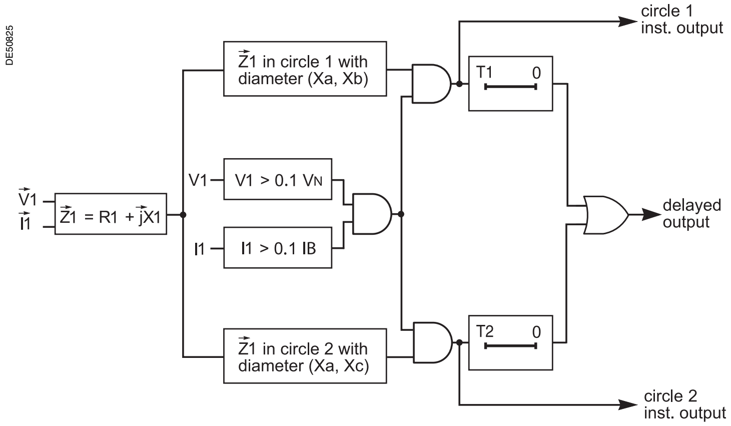
- Case of a generator main or motor feeder

| | Circle 1 | Circle 2 |
|---|---|---|
| Center | C1 = -(Xa + Xb)/2 | C2 = -(Xa + Xc)/2 |
| Radius | R1 = (Xb - Xa)/2 | R2 = (Xc - Xa)/2 |

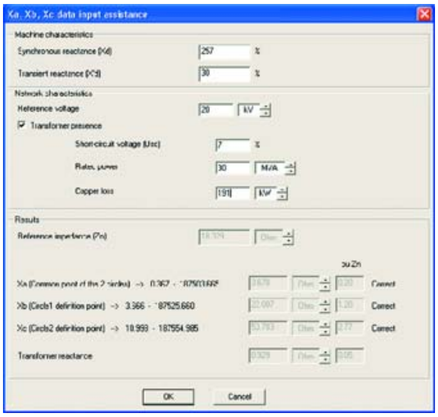
- Case of a generator feeder or motor main:  
  the tripping characteristics are symmetrical with respect to the R axis

| | Circle 1 | Circle 2 |
|---|---|---|
| Center | C1 = (Xa + Xb)/2 | C2 = (Xa + Xc)/2 |
| Radius | R1 = (Xb - Xa)/2 | R2 = (Xc - Xa)/2 |

## Block Diagram


DE50825
circle 1
inst. output
Z1 in circle 1 with diameter (Xa, Xb)
T1 0
V1
V1 > 0.1 VN
I1
I1 > 0.1 IB
V1
I1
Z1 = R1 + jX1
delayed output
Z1 in circle 2 with diameter (Xa, Xc)
T2 0
circle 2
inst. output

# Loss of Field
ANSI Code 40



Synchronous reactance (Xd) 257 %
Transient reactance (X'd) 30 %
Reference voltage 20 kV
☑ Transformer presence
Short-circuit voltage (Usc) 7 %
Rated power 30 MVA
Copper loss 191 kW
Reference impedance (Zn)
Xa (Common point of the 2 circles) -> 0.367 - [illegible]
Xb (Circle1 definition point) -> 3.366 - 187525.660
Xc (Circle2 definition point) -> 18.993 - 187554.985
Transformer reactance

## SFT2841 Setting Help

The SFT2841 software includes a setting assistance function to calculate the values of Xa, Xb and Xc according to the electrical characteristics of the machine (and transformer, when applicable).
Data used:

- synchronous machine:
  - synchronous reactance Xd in%
  - transient synchronous reactance X'd in%
- transformer:
  - winding 1 voltage $V_{LL}N1$ in V/kV
  - short-circuit voltage $V_{LL}sc$ in %
  - rated power in kVA/MVA
  - copper losses in kΩ/MΩ.

The proposed settings are circle one with a diameter $Z_N$ if Xd ≥ 200% or a diameter Xd/2 in all other cases, and circle two with a diameter Xd.
The two circles are offset from zero by -X'd/2.
$Z_N$ = the rated machine impedance:

$$Z_N = \frac{V_{LL1}}{\sqrt{3}I_B}.$$

## Characteristics

| **Settings** | |
|---|---|
| **Common Point: Xa** | |
| Setting range | $0.02V_N/I_B \leq Xa \leq 0.20V_N/I_B + 187.5$ kΩ or 0.001 Ω |
| Accuracy (1) | ±5% |
| Resolution | 1% |
| **Circle 1: Xb** | |
| Setting range | $0.20V_N/I_B \leq Xa \leq 1.40V_N/I_B + 187.5$ kΩ |
| Accuracy (1) | ±5% |
| Resolution | 0.001 Ω or 1 digit |
| Drop out/pick up ratio | 105% of circle 1 diameter |
| **Circle 2: Xc** | |
| Setting range | $0.60V_N/I_B \leq Xa \leq 3V_N/I_B + 187.5$ kΩ |
| Accuracy (1) | ±5% |
| Resolution | 0.001 Ω or 1 digit |
| Drop out/pick up ratio | 105% of circle 2 diameter |
| **T1 Time: Tripping Time Delay Circle 1** | |
| Setting range | 50 ms ≤ T ≤ 300 s |
| Accuracy (1) | ±2% or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |
| **T2 time: Tripping Time Delay Circle 2** | |
| Setting range | 100 ms ≤ T ≤ 300 s |
| Accuracy (1) | ±2% or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |
| **Characteristic Times (1)** | |
| Operation time | Pick-up < 35 ms from 0 to C1 (typically 25 ms)<br>Pick-up < 35 ms from 0 to C2 (typically 25 ms) |
| Overshoot time | < 40 ms |
| Reset time | < 50 ms (for T1 = 0) |

| **Inputs** | | | |
|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** |
| Protection reset | P40_1_101 | ■ | ■ |
| Protection blocking | P40_1_113 | ■ | ■ |

| **Outputs** | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P40_1_1 | ■ | ■ | |
| Delayed output | P40_1_3 | ■ | ■ | ■ |
| Protection blocked | P40_1_16 | ■ | ■ | |
| Instantaneous protection 1 (circle 1) | P40_1_23 | ■ | ■ | |

*(1) Under reference conditions (IEC 60255-6).*

## Example 1. Synchronous Generator

**Synchronous Generator Data**

- S = 3.15 MVA
- $V_{LL}N1$ = 6.3 kV
- Xd = 233%
- X'd = 21%

**Protection setting**

To set the protection function, it is necessary to calculate the rated generator impedance $Z_N$:

- **$I_B = S/(\sqrt{3}.V_{LL}N1) = 289$ A**
- **$Z_N = V_{LL}N1/(\sqrt{3}.IB) = 12.586\ \Omega$.**

Generally speaking, circle 1 is set with a diameter $Z_N$, offset by -X'd/2, and circle 2 is set with a diameter Xd, offset by -X'd/2:

- **$Xa = (X'd(\%)/200)Z_N = 1.321\ \Omega$**
- **$Xb = (X'd(\%)/200 + 1)Z_N = 13.907\ \Omega$**
- **$Xc = (X'd(\%)/200 + X1/100)Z_N = 30.646\ \Omega$.**

The faults detected in circle 1 are violent field-loss faults that must be cleared rapidly. Circle 2 may concern faults other than field-loss faults and its tripping time is longer:

- T1 = 70 ms
- T2 = 500 ms.

## Example 2. Generator-Transformer Unit Applications

**Synchronous Generator Data**

- S_gen = 19 MVA
- $V_{LL}N2$ = 5.5 kV
- Xd = 257%
- X'd= 30%

**Transformer Data**

- S_tx = 30 MVA
- $V_{LL}N1$ = 20 kV / Vn2 = 5.5 kV
- % Z = 7%
- Pcu = 191 kW (Load Losses (in kW) from TX test report)

**Protection Setting**

To set the protection function, it is necessary to calculate the rated generator impedance at voltage Vn1:

- **$Z_N=(20kV)^2/19MVA$**
- **$Z_N = 21.05$.**

The transformer impedance at voltage Vn1 is:
Z_tx (in MVA)= %Z/100($kV_{LL}N1)^2$/S_tx (in MVA) = 0.933 Ω.
The transformer resistance at voltage $V_{LL}N1$ is:
R_tx = Pcu/1000($V_{LL}N1$/S_tx$)^2$ = 0.085 Ω.
The transformer reactance at voltage $V_{LL}N1$ is:

$$Xtx = \sqrt{Ztx^2 - Rtx^2} = 0.929\Omega$$

.

Circle 1 is set with a diameter Zn, offset by -X'd/2 and the transformer reactance.
Circle 2 is set with a diameter Xd, offset by -X'd/2 and the transformer reactance.

- **$Xa = (X'd(\%)/200)Z_N + X\_tx = 4.09\ \Omega$**
- **$Xb = (X'd(\%)/200 + 1)Z_N + X\_tx = 24.2\ \Omega$**
- **$Xc = (X'd(\%)/200 + X1(\%)/100)Z_N + X\_tx = 57.1\ \Omega$.**

The faults detected in circle 1 are violent field-loss faults that must be cleared rapidly. Circle 2 may concern faults other than field-loss faults and its tripping time is longer:

- T1 = 70 ms
- T2 = 500 ms.

# Negative Sequence/ Current Unbalance
## ANSI Code 46

*Phase unbalance protection for lines and equipment.*

### Description

This function provides protection against phase unbalance, which is detected by measuring negative sequence current:

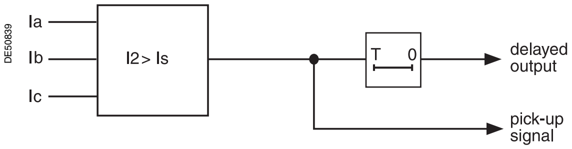
- sensitive protection to detect 2-phase faults at the ends of long lines
- protection of equipment against temperature rise, caused by an unbalanced power supply, phase inversion or loss of phase, and against phase current unbalance.

This function enables if the negative sequence current is greater than the operation set point.

The time delay may be definite time or IDMT, according to a standardized curve, a specially adapted Schneider curve, or an $I^2R$ curve for generator protection.

| **Tripping Curve** |
|---|
| Schneider IDMT |
| IEC inverse time SIT / A |
| IEC very inverse time VIT or LTI / B |
| IEC extremely inverse time EIT / C |
| IEEE moderately inverse (IEC / D) |
| IEEE very inverse (IEC / E) |
| IEEE extremely inverse (IEC / F) |
| $I^2R$ curve |

### Block Diagram



### Characteristics

| **Settings** | | |
|---|---|---|
| **Measurement Origin** | | |
| Setting range | | Main channels (I)<br>Additional channels (I') |
| **Tripping Curve** | | |
| Setting range | | See list above |
| **Is Set Point** | | |
| Setting range | definite time | 10% to 500% of IB or I'B |
| | Schneider IDMT | 10% to 50% of IB or I'B |
| | IEC or IEEE IDMT | 10% to 100% of IB or I'B |
| | $I^2R$ curve | 3% to 20% of IB or I'B |
| Accuracy (1) | | ±5% or ±0.004 $I_N$ |
| Resolution | | 1% |
| Drop out/pick up ratio | | 93.5% ±5% or > (1 - 0.005 $I_N$/Is) x 100% |
| **Time Delay T** | | |
| Setting range | definite time | 100 ms ≤ T ≤ 300 s |
| | IDMT | 100 ms ≤ T ≤ 1 s or TMS (2) |
| Accuracy (1) | definite time | ±2% or +25 ms |
| | IDMT | ±5% or +35 ms |
| Resolution | | 10 ms or 1 digit |
| **K ($I_2^2t$ Curve Only)** | | |
| Setting range | | 1 to 100 |
| Resolution | | 1 |
| **Characteristic Times** | | |
| Operation time | | Pick-up < 55 ms at 2 Is |
| Overshoot time | | < 50 ms at 2 Is |
| Reset time | | < 55 ms at 2 Is |

**Inputs**

| **Designation** | **Syntax** | **Equations** | **Logipam** |
|---|---|---|---|
| Protection reset | P46_x_101 | ■ | ■ |
| Protection blocking | P46_x_113 | ■ | ■ |

**Outputs**

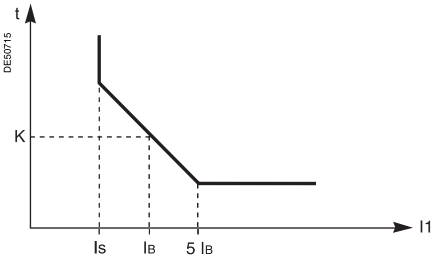
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
|---|---|---|---|---|
| Instantaneous output (pick-up) | P46_x_1 | ■ | ■ | |
| Delayed output | P46_x_3 | ■ | ■ | ■ |
| Protection blocked | P46_x_16 | ■ | ■ | |

*x: unit number.*

***(1)*** *Under reference conditions (IEC 60255-6).*

***(2)*** *Setting ranges in TMS (Time Multiplier Setting) mode:*
*Inverse (SIT) and IEC SIT/A: 0.034 to 0.336*
*Very inverse (VIT) and IEC VIT/B: 0.067 to 0.666*
*Very inverse (LTI) and IEC LTI/B: 0.008 to 0.075*
*Ext. inverse (EIT) and IEC EIT/C: 0.124 to 1.237*
*IEEE moderately inverse : 0.415 to 4.142*
*IEEE very inverse : 0.726 to 7.255*
*IEEE extremely inverse : 1.231 to 12.30.*

# Negative Sequence/ Current Unbalance
## ANSI Code 46



$I_2^2t$ curve.

### Setting Example for $I_2^2t$ curves

A generator can handle a certain level of negative sequence current on a continuous basis. The continuous level (Is), indicated by the manufacturer, is generally between 5 and 10% of the base current IB.
Typical values are:

| Type of Generator | | I2 permissible (% Ib) |
|---|---|---|
| Salient poles | with amortisseur windings | 10 |
| | without amortisseur windings | 5 |
| Cylindrical rotors | Indirectly cooled | 10 |
| | Sn ≤ 960 MVA | 8 |
| | 960 MVA < Sn ≤ 1200 MVA | 6 |
| | 1200 MVA < Sn | 5 |

*Reference IEEE C37.102-1987.*

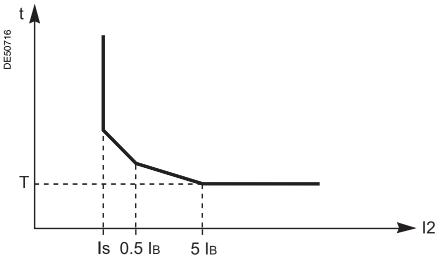
When this current level is exceeded, the generator can handle a negative sequence current I2 for a time td, corresponding to the following equation:

$$td = \frac{K}{\left(\frac{|\vec{I}_2|}{IB}\right)^2}$$

The K value is an adjustable constant that depends on the type of generator, generally between 1 and 40. Typical values of K are:

| Type of Generator | | K |
|---|---|---|
| Salient poles | | 40 |
| Synchronous condenser | | 30 |
| Cylindrical rotors | Indirectly cooled | 20 |
| | Sn ≤ 800 MVA | 10 |
| | 800 MVA < Sn ≤ 1600 MVA | 10 - 0.00625.(MVA - 800) |

*Reference IEEE C37.102-1987.*



*Schneider curve.*

### Schneider IDMT Curve

For I2 > Is, the time delay depends on the value of I2/IB (IB: base current of the protected equipment defined when the general parameters are set).

T corresponds to the time delay for I2/IB = 5.

The tripping curve is defined according to the following equations:

- for Is/IB ≤ I2/IB ≤ 0.5
  $$t = \frac{3.19}{(I2/(IB))^{1.5}} \times T$$
- for 0.5 ≤ I2/IB ≤ 5
  $$t = \frac{4.64}{(I2/IB)^{0.96}} \times T$$
- for I2/IB > 0.5
  **t = T**

# Negative Sequence/ Current Unbalance
## ANSI Code 46

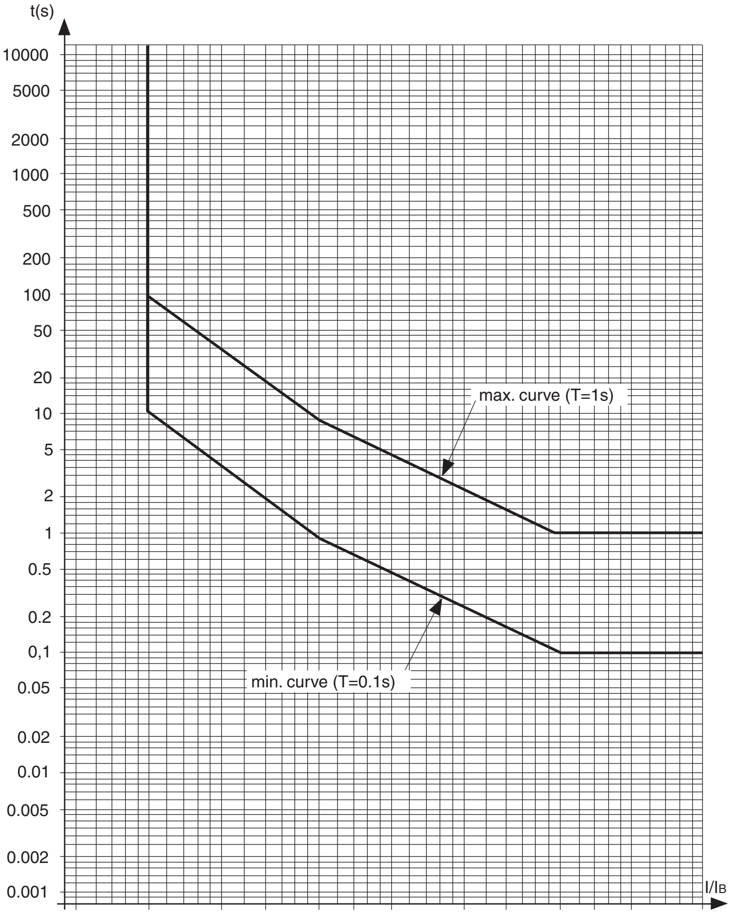
### Determination of tripping time for different negative sequence current values for a given Schneider curve

Use the table to find the value of X that corresponds to the required negative sequence current. The tripping time is equal to XT.

**Example**

given a tripping curve with the setting T = 0.5 s.
What is the tripping time at 0.6 IB?
Use the table to find the value of X that corresponds to 60% of IB.
The table indicates X = 7.55. The tripping time is equal to: 0.5 x 7.55 = 3.755 s.

**Schneider IDMT Tripping Curve**



| **I2 (% IB)** | 10 | 15 | 20 | 25 | 30 | 33.33 | 35 | 40 | 45 | 50 | 55 | 57.7 | 60 | 65 | 70 | 75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **X** | 99.95 | 54.50 | 35.44 | 25.38 | 19.32 | 16.51 | 15.34 | 12.56 | 10.53 | 9.00 | 8.21 | 7.84 | 7.55 | 7.00 | 6.52 | 6.11 |
| **I2 (% IB)** cont. | 80 | 85 | 90 | 95 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | 210 |
| **X** cont. | 5.74 | 5.42 | 5.13 | 4.87 | 4.64 | 4.24 | 3.90 | 3.61 | 3.37 | 3.15 | 2.96 | 2.80 | 2.65 | 2.52 | 2.40 | 2.29 |
| **I2 (% IB)** cont. | 220 | 230 | 240 | 250 | 260 | 270 | 280 | 290 | 300 | 310 | 320 | 330 | 340 | 350 | 360 | 370 |
| **X** cont. | 2.14 | 2.10 | 2.01 | 1.94 | 1.86 | 1.80 | 1.74 | 1.68 | 1.627 | 1.577 | 1.53 | 1.485 | 1.444 | 1.404 | 1.367 | 1.332 |
| **I2 (% IB)** cont. | 380 | 390 | 400 | 410 | 420 | 430 | 440 | 450 | 460 | 470 | 480 | 490 | ⩾ 500 | | | |
| **X** cont. | 1.298 | 1.267 | 1.236 | 1.18 | 1.167 | 1.154 | 1.13 | 1.105 | 1.082 | 1.06 | 1.04 | 1.02 | 1 | | | |

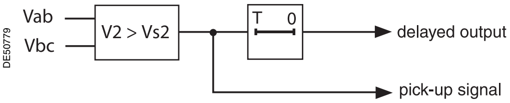
# Negative Sequence Overvoltage
ANSI Code 47

*Phase unbalance protection.*

## Description

This function provides protection against phase unbalance resulting from phase inversion, unbalanced supply or distant fault. Overvoltage is detected by measuring negative sequence voltage V2. It does not operate when Sepam™ uses only a single phase voltage. It includes a definite time delay T.

## Block Diagram



## Characteristics

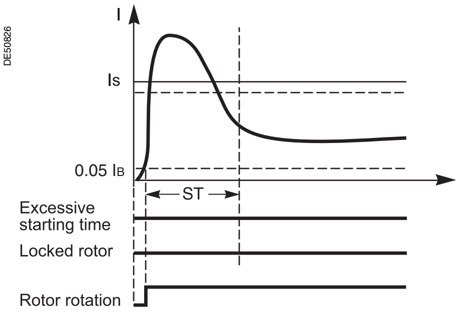
| | | | | |
|---|---|---|---|---|
| **Settings** | | | | |
| **Measurement Origin** | | | | |
| Setting range | Main channels ($V_{LL}$) / Additional channels ($V_{LL}$') | | | |
| **Vs2 Set Point** | | | | |
| Setting range | 1% to 50% of $V_{LL}$Np | | | |
| Accuracy (1) | ±2% or 0.005 $V_{LL}$Np | | | |
| Resolution | 1% | | | |
| Drop out/pick up ratio | 97% ±1% or > (1 - 0.006 $V_{LL}$Np/Vs2) x 100% | | | |
| **Time Delay T** | | | | |
| Setting range | 50 ms to 300 s | | | |
| Accuracy (1) | ±2% or ±25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Characteristic Times** | | | | |
| Operation time | Pick-up < 40 ms at 2 Vs2 | | | |
| Overshoot time | < 50 ms at 2 Vs2 | | | |
| Reset time | < 50 ms at 2 Vs2 | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P47_x_101 | ■ | ■ | |
| Protection blocking | P47_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P47_x_1 | ■ | ■ | |
| Delayed output | P47_x_3 | ■ | ■ | ■ |
| Protection blocked | P47_x_16 | ■ | ■ | |

*x: unit number.*
***(1)** Under reference conditions (IEC 60255-6).*

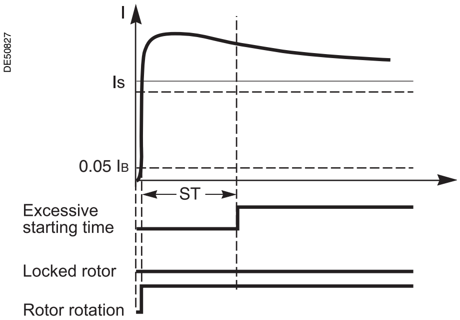
# Excessive Starting Time, Locked Rotor

## ANSI Code 48/51LR

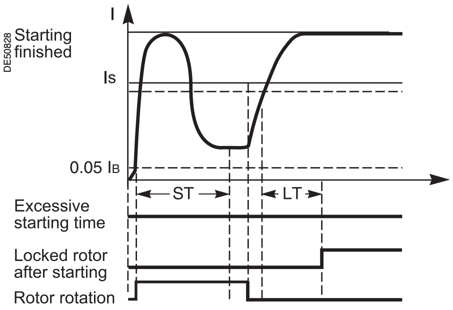
*Detection of excessive starting time and locked rotors for motor protection.*



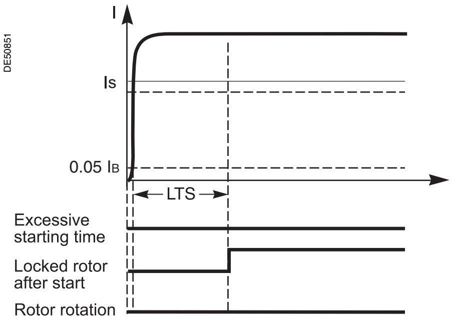
*Case of normal starting.*



*Case of excessive starting time*



*Case of jammed or stalled rotor*



*Case of locked rotor at start*

## Operation

This function is three-phase:

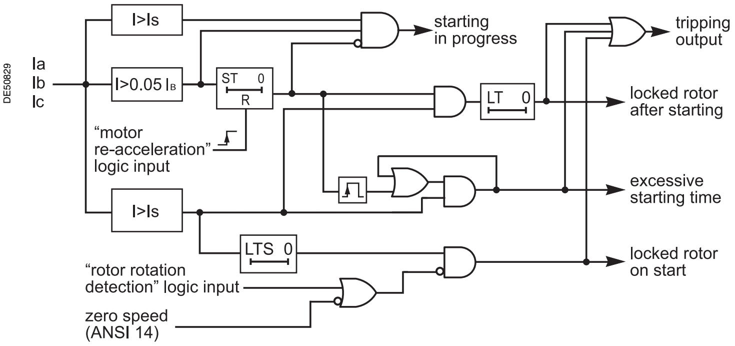
1. **Excessive starting time (ST).** During start sequence, the protection enables when one of the three phase currents is greater than the set point **Is** due to overloads (e.g. conveyor) or insufficient supply voltage
2. **Locked rotor (LT).** At the normal operating rate (after starting) the protection enables when one of the three phase currents is greater than the set point **Is** for a period of time that is longer than the LT time delay of the definite time type.
3. If the rotor is **locked on start (LTS)**: Large motors may have very long starting times (due to inertia) or a reduced voltage supply. This starting time is longer than the permissible rotor blocking time. To protect such a motor, the LTS timer initiates a trip if a start is detected (I > Is), or if the motor speed is zero. For a normal start, the input I23 (zero-speed-switch) disables this protection.

### Motor Acceleration

When a motor accelerates, it consumes a level of current in the vicinity of the starting current (> Is) without the current first passing through a value less than 10% of IB. The ST time delay (which corresponds to the normal starting time) can be reinitialised by the logic input "motor re-acceleration."

This will reinitialize the **excessive starting time** protection and set the **locked rotor** protection LT time delay to a low value.

## Block Diagram


DE50829
Ia
Ib
Ic
I>Is
I>0.05 IB
ST 0
R
"motor re-acceleration" logic input
I>Is
LTS 0
LT 0
"rotor rotation detection" logic input
zero speed (ANSI 14)
starting in progress
tripping output
locked rotor after starting
excessive starting time
locked rotor on start

# Excessive Starting Time, Locked Rotor

## ANSI Code 48/51LR

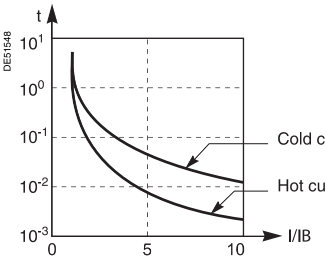
### Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Is Set Point** | | | | |
| Setting range | | 50% to 500% of IB | | |
| Accuracy (1) | | ±5% | | |
| Resolution | | 1% | | |
| Drop out/pick up ratio | | 93% | | |
| **Time Delay T** | | | | |
| Setting range | ST | 500 ms to 300 s | | |
| | LT | 50 ms to 300 s | | |
| | LTS | 50 ms to 300 s | | |
| Accuracy (1) | | 2% or ±25 ms | | |
| Resolution | | 10 ms | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P48/51LR_1_101 | ■ | ■ | |
| Motor re-acceleration | P48/51LR_1_102 | ■ | ■ | |
| Protection blocking | P48/51LR_1_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Protection output | P48/51LR_1_3 | ■ | ■ | ■ |
| Locked rotor | P48/51LR_1_13 | ■ | ■ | ■ |
| Excessive starting time | P48/51LR_1_14 | ■ | ■ | ■ |
| Locked rotor at start-up | P48/51LR_1_15 | ■ | ■ | ■ |
| Protection blocked | P48/51LR_1_16 | ■ | ■ | |
| Starting in progress | P48/51LR_1_22 | ■ | ■ | |

***(1)** Under reference conditions (IEC 60255-6).*

# Thermal Overload for Cables
## ANSI Code 49RMS

*Protection of cables against thermal damage caused by overloads.*



*Tripping curves.*

### Description

This protection function is used to protect cables against overloads, based on measurement of the current drawn.
The current measured by the thermal protection is an RMS 3-phase current, which factors harmonics up to the 13th level. The highest current of the three phases is used to calculate for heat rise:

$$\mathbf{Iph} = \mathbf{max}(Ia, Ib, Ic).$$

The calculated heat rise, proportional to the square of the current drawn, depends on the current drawn and the previous temperature status. Under steady-state conditions, it is equal to:

$$\mathbf{E} = \left(\frac{\mathbf{Iph}}{IB}\right)^2 \times \mathbf{100} \quad \text{in\%}$$

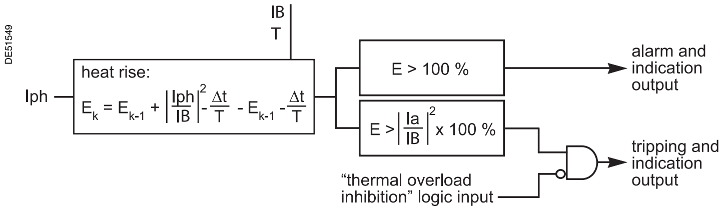
The protection function issues the trip command when the phase current is greater than the permissible current for the cable. The value of the base current IB must absolutely be less than the permissible current Ia. By default, we use IB ≈ Ia/1.4.
The protection tripping time is set by the time constant T.

Cold curve: $$\frac{\mathbf{t}}{\mathbf{T}} = \mathbf{ln}\left(\frac{\left(\frac{\mathbf{I}}{IB}\right)^2}{\left(\frac{\mathbf{I}}{IB}\right)^2 - \left(\frac{\mathbf{Ia}}{IB}\right)^2}\right)$$ where ln: natural logarithm.

Hot curve: $$\frac{\mathbf{t}}{\mathbf{T}} = \mathbf{ln}\left(\frac{\left(\frac{\mathbf{I}}{IB}\right)^2 - \mathbf{1}}{\left(\frac{\mathbf{I}}{IB}\right)^2 - \left(\frac{\mathbf{Ia}}{IB}\right)^2}\right)$$ where ln: natural logarithm.

The present heat rise is saved in the event of an auxiliary power failure.

### Block Diagram


DE51549
IB
T
Iph
heat rise:
$E_k = E_{k-1} + \left|\frac{Iph}{IB}\right|^2 \cdot \frac{\Delta t}{T} - E_{k-1} \cdot \frac{\Delta t}{T}$
E > 100 %
$E > \left|\frac{Ia}{IB}\right|^2 \times 100\ \%$
alarm and indication output
tripping and indication output
"thermal overload inhibition" logic input

### User Information

The following information is available for the user:

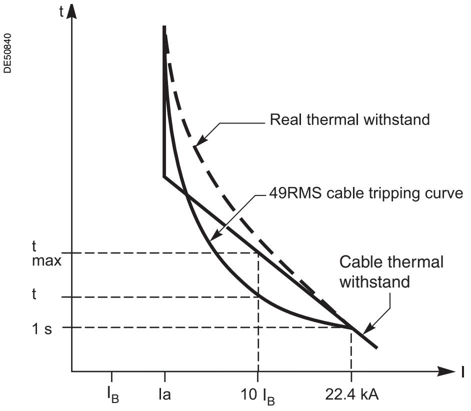
- heat rise
- time before tripping (with constant current).

### Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Permissible Current Ia** | | | | |
| Setting range | < 1 to 1.73 IB | | | |
| Accuracy (1) | ±2% | | | |
| Resolution | 1 A | | | |
| **Time Constant T** | | | | |
| Setting range | 1 min. to 600 min. | | | |
| Resolution | 1 min. | | | |
| **Characteristic Times (1)** | | | | |
| Operation time accuracy | ±2% or ±1 s | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P49RMS_1_101 | ■ | ■ | |
| Protection blocking | P49RMS_1_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Delayed output | P49RMS_1_3 | ■ | ■ | ■ |
| Alarm | P49RMS_1_10 | ■ | ■ | ■ |
| Block closing | P49RMS_1_11 | ■ | ■ | ■ |
| Protection blocked | P49RMS_1_16 | ■ | ■ | |
| Hot state | P49RMS_1_18 | ■ | ■ | |
| Block thermal overload | P49RMS_1_32 | ■ | ■ | |

***(1)** Under reference conditions (IEC 60255-6).*

# Thermal Overload for Cables
## ANSI Code 49RMS



### Example

Consider a copper cable, 350MCM, with a permissible current Ia = 485 A and a 1- second thermal withstand Ith_1 s = 22.4 kA.

The thermal time constant of a cable depends on its installation method. Typical time-constant values are between 10 and 60 minutes. For buried cables, the time constant is between 20 and 60 minutes, for non-buried cables, it is between 10 and 40 minutes.

For the cable in question, the selected values are T = 30 minutes and IB = 350 A.

**Check compatibility between the 49RMS curve and the cable thermal withstand curve.**

Conditions are correct at 10 IB.

In the range of currents close to the permissible current, the 1-second thermal withstand is used to estimate maximum thermal withstand for the cable, assuming there are no heat exchanges. The maximum tripping time is calculated as:

**$I^2$ x tmax = constant = (Ith_1 s)$^2$ x 1**.

For the cable in question and at 10 IB:

**tmax = (Ith_1 s/ I0Ib)$^2$ = (22400 / 3500)$^2$ = 41 s**.

For I = 10 IB = 3500 A and Ia/IB = 1.38, the value of k in the cold tripping curve table is k ≈ 0.0184.

The tripping time at 10 IB is therefore:

**t = k x T x 60 = 0.0184 x 30 x 60 = 35.6s < tmax**.

For a 10 IB fault occuring after a rated operation phase, with 100% heat rise, the value of k is : k ≈ 0.0097.

The tripping time is:

**t = k x T x 60 = 0.0097 x 30 x 60 = 17.5 s**

**Coordination Check**

Coordination between 49RMS for the cable and the downstream protection curves (including 49RMS Protection Functions) must be checked to avoid any risk of nuisance tripping.

# Thermal Overload for Cables
## ANSI Code 49RMS
### Trip Curves

**Curves for Initial Heat Rise = 0%(1)**

| Iph/IB<br>Ia/IB | 0.55 | 0.60 | 0.65 | 0.70 | 0.75 | 0.80 | 0.85 | 0.90 | 0.95 | 1.00 | 1.05 | 1.10 | 1.15 | 1.20 | 1.25 | 1.30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.50** | 1.7513 | 1.1856 | 0.8958 | 0.7138 | 0.5878 | 0.4953 | 0.4247 | 0.3691 | 0.3244 | 0.2877 | 0.2572 | 0.2314 | 0.2095 | 0.1907 | 0.1744 | 0.1601 |
| **0.55** |  | 1.8343 | 1.2587 | 0.9606 | 0.7717 | 0.6399 | 0.5425 | 0.4675 | 0.4082 | 0.3603 | 0.3207 | 0.2877 | 0.2597 | 0.2358 | 0.2152 | 0.1972 |
| **0.60** |  |  | 1.9110 | 1.3269 | 1.0217 | 0.8267 | 0.6897 | 0.5878 | 0.5090 | 0.4463 | 0.3953 | 0.3531 | 0.3178 | 0.2877 | 0.2619 | 0.2396 |
| **0.65** |  |  |  | 1.9823 | 1.3907 | 1.0793 | 0.8789 | 0.7373 | 0.6314 | 0.5491 | 0.4832 | 0.4295 | 0.3849 | 0.3473 | 0.3153 | 0.2877 |
| **0.70** |  |  |  |  | 2.0488 | 1.4508 | 1.1338 | 0.9287 | 0.7829 | 0.6733 | 0.5878 | 0.5191 | 0.4629 | 0.4159 | 0.3763 | 0.3424 |
| **0.75** |  |  |  |  |  | 2.1112 | 1.5075 | 1.1856 | 0.9762 | 0.8267 | 0.7138 | 0.6253 | 0.5540 | 0.4953 | 0.4463 | 0.4047 |
| **0.80** |  |  |  |  |  |  | 2.1699 | 1.5612 | 1.2349 | 1.0217 | 0.8687 | 0.7527 | 0.6615 | 0.5878 | 0.5270 | 0.4759 |
| **0.85** |  |  |  |  |  |  |  | 2.2254 | 1.6122 | 1.2819 | 1.0652 | 0.9091 | 0.7904 | 0.6966 | 0.6206 | 0.5578 |
| **0.90** |  |  |  |  |  |  |  |  | 2.2780 | 1.6607 | 1.3269 | 1.1069 | 0.9480 | 0.8267 | 0.7306 | 0.6526 |
| **0.95** |  |  |  |  |  |  |  |  |  | 2.3279 | 1.7070 | 1.3699 | 1.1470 | 0.9855 | 0.8618 | 0.7636 |
| **1.00** |  |  |  |  |  |  |  |  |  |  | 2.3755 | 1.7513 | 1.4112 | 1.1856 | 1.0217 | 0.8958 |
| **1.05** |  |  |  |  |  |  |  |  |  |  |  | 2.4209 | 1.7937 | 1.4508 | 1.2228 | 1.0566 |
| **1.10** |  |  |  |  |  |  |  |  |  |  |  |  | 2.4643 | 1.8343 | 1.4890 | 1.2587 |
| **1.15** |  |  |  |  |  |  |  |  |  |  |  |  |  | 2.5060 | 1.8734 | 1.5258 |
| **1.20** |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2.5459 | 1.9110 |
| **1.25** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 2.5844 |

| Iph/IB<br>Ia/IB | 1.35 | 1.40 | 1.45 | 1.50 | 1.55 | 1.60 | 1.65 | 1.70 | 1.75 | 1.80 | 1.85 | 1.90 | 1.95 | 2.00 | 2.20 | 2.40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.50** | 0.1475 | 0.1365 | 0.1266 | 0.1178 | 0.1099 | 0.1028 | 0.0963 | 0.0905 | 0.0852 | 0.0803 | 0.0759 | 0.0718 | 0.0680 | 0.0645 | 0.0530 | 0.0444 |
| **0.55** | 0.1815 | 0.1676 | 0.1553 | 0.1444 | 0.1346 | 0.1258 | 0.1178 | 0.1106 | 0.1040 | 0.0980 | 0.0925 | 0.0875 | 0.0829 | 0.0786 | 0.0645 | 0.0539 |
| **0.60** | 0.2201 | 0.2029 | 0.1878 | 0.1744 | 0.1623 | 0.1516 | 0.1418 | 0.1330 | 0.1251 | 0.1178 | 0.1111 | 0.1051 | 0.0995 | 0.0943 | 0.0773 | 0.0645 |
| **0.65** | 0.2637 | 0.2428 | 0.2243 | 0.2080 | 0.1934 | 0.1804 | 0.1686 | 0.1581 | 0.1485 | 0.1397 | 0.1318 | 0.1245 | 0.1178 | 0.1116 | 0.0913 | 0.0762 |
| **0.70** | 0.3132 | 0.2877 | 0.2653 | 0.2456 | 0.2281 | 0.2125 | 0.1984 | 0.1858 | 0.1744 | 0.1640 | 0.1545 | 0.1459 | 0.1380 | 0.1307 | 0.1067 | 0.0889 |
| **0.75** | 0.3691 | 0.3383 | 0.3113 | 0.2877 | 0.2667 | 0.2481 | 0.2314 | 0.2165 | 0.2029 | 0.1907 | 0.1796 | 0.1694 | 0.1601 | 0.1516 | 0.1236 | 0.1028 |
| **0.80** | 0.4326 | 0.3953 | 0.3630 | 0.3347 | 0.3098 | 0.2877 | 0.2680 | 0.2503 | 0.2344 | 0.2201 | 0.2070 | 0.1952 | 0.1843 | 0.1744 | 0.1418 | 0.1178 |
| **0.85** | 0.5049 | 0.4599 | 0.4210 | 0.3873 | 0.3577 | 0.3316 | 0.3084 | 0.2877 | 0.2691 | 0.2523 | 0.2371 | 0.2233 | 0.2107 | 0.1992 | 0.1617 | 0.1340 |
| **0.90** | 0.5878 | 0.5332 | 0.4866 | 0.4463 | 0.4112 | 0.3804 | 0.3531 | 0.3289 | 0.3072 | 0.2877 | 0.2701 | 0.2541 | 0.2396 | 0.2263 | 0.1832 | 0.1516 |
| **0.95** | 0.6836 | 0.6170 | 0.5608 | 0.5127 | 0.4710 | 0.4347 | 0.4027 | 0.3744 | 0.3491 | 0.3265 | 0.3061 | 0.2877 | 0.2710 | 0.2557 | 0.2064 | 0.1704 |
| **1.00** | 0.7956 | 0.7138 | 0.6456 | 0.5878 | 0.5383 | 0.4953 | 0.4578 | 0.4247 | 0.3953 | 0.3691 | 0.3456 | 0.3244 | 0.3052 | 0.2877 | 0.2314 | 0.1907 |
| **1.05** | 0.9287 | 0.8267 | 0.7431 | 0.6733 | 0.6142 | 0.5633 | 0.5191 | 0.4804 | 0.4463 | 0.4159 | 0.3888 | 0.3644 | 0.3424 | 0.3225 | 0.2585 | 0.2125 |
| **1.10** | 1.0904 | 0.9606 | 0.8569 | 0.7717 | 0.7005 | 0.6399 | 0.5878 | 0.5425 | 0.5027 | 0.4675 | 0.4363 | 0.4082 | 0.3830 | 0.3603 | 0.2877 | 0.2358 |
| **1.15** | 1.2934 | 1.1231 | 0.9916 | 0.8862 | 0.7996 | 0.7269 | 0.6651 | 0.6118 | 0.5654 | 0.5246 | 0.4884 | 0.4563 | 0.4274 | 0.4014 | 0.3192 | 0.2609 |
| **1.20** | 1.5612 | 1.3269 | 1.1549 | 1.0217 | 0.9147 | 0.8267 | 0.7527 | 0.6897 | 0.6353 | 0.5878 | 0.5460 | 0.5090 | 0.4759 | 0.4463 | 0.3531 | 0.2877 |
| **1.25** | 1.9473 | 1.5955 | 1.3593 | 1.1856 | 1.0509 | 0.9425 | 0.8531 | 0.7780 | 0.7138 | 0.6583 | 0.6098 | 0.5671 | 0.5292 | 0.4953 | 0.3898 | 0.3165 |
| **1.30** | 2.6214 | 1.9823 | 1.6286 | 1.3907 | 1.2155 | 1.0793 | 0.9696 | 0.8789 | 0.8026 | 0.7373 | 0.6808 | 0.6314 | 0.5878 | 0.5491 | 0.4295 | 0.3473 |
| **1.35** |  | 2.6571 | 2.0161 | 1.6607 | 1.4212 | 1.2445 | 1.1069 | 0.9959 | 0.9041 | 0.8267 | 0.7604 | 0.7029 | 0.6526 | 0.6081 | 0.4725 | 0.3804 |
| **1.40** |  |  | 2.6915 | 2.0488 | 1.6918 | 1.4508 | 1.2727 | 1.1338 | 1.0217 | 0.9287 | 0.8502 | 0.7829 | 0.7245 | 0.6733 | 0.5191 | 0.4159 |
| **1.45** |  |  |  | 2.7249 | 2.0805 | 1.7220 | 1.4796 | 1.3001 | 1.1601 | 1.0467 | 0.9527 | 0.8733 | 0.8050 | 0.7458 | 0.5699 | 0.4542 |
| **1.50** |  |  |  |  | 2.7571 | 2.1112 | 1.7513 | 1.5075 | 1.3269 | 1.1856 | 1.0712 | 0.9762 | 0.8958 | 0.8267 | 0.6253 | 0.4953 |
| **1.55** |  |  |  |  |  | 2.7883 | 2.1410 | 1.7797 | 1.5347 | 1.3529 | 1.2106 | 1.0952 | 0.9992 | 0.9179 | 0.6859 | 0.5397 |
| **1.60** |  |  |  |  |  |  | 2.8186 | 2.1699 | 1.8074 | 1.5612 | 1.3783 | 1.2349 | 1.1185 | 1.0217 | 0.7527 | 0.5878 |
| **1.65** |  |  |  |  |  |  |  | 2.8480 | 2.1980 | 1.8343 | 1.5870 | 1.4031 | 1.2587 | 1.1414 | 0.8267 | 0.6399 |
| **1.70** |  |  |  |  |  |  |  |  | 2.8766 | 2.2254 | 1.8605 | 1.6122 | 1.4272 | 1.2819 | 0.9091 | 0.6966 |

*(1) Ia is the permissible current for the cable.*

### Curves for Initial Heat Rise = 0%(1)

| Iph/IB Ia/IB | 2.60 | 2.80 | 3.00 | 3.20 | 3.40 | 3.60 | 3.80 | 4.00 | 4.20 | 4.40 | 4.60 | 4.80 | 5.00 | 5.50 | 6.00 | 6.50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **0,50** | 0.0377 | 0.0324 | 0.0282 | 0.0247 | 0.0219 | 0.0195 | 0.0175 | 0.0157 | 0.0143 | 0.0130 | 0.0119 | 0.0109 | 0.0101 | 0.0083 | 0.0070 | 0.0059 |
| **0.55** | 0.0458 | 0.0393 | 0.0342 | 0.0300 | 0.0265 | 0.0236 | 0.0212 | 0.0191 | 0.0173 | 0.0157 | 0.0144 | 0.0132 | 0.0122 | 0.0101 | 0.0084 | 0.0072 |
| **0.60** | 0.0547 | 0.0470 | 0.0408 | 0.0358 | 0.0316 | 0.0282 | 0.0252 | 0.0228 | 0.0206 | 0.0188 | 0.0172 | 0.0157 | 0.0145 | 0.0120 | 0.0101 | 0.0086 |
| **0.65** | 0.0645 | 0.0554 | 0.0481 | 0.0421 | 0.0372 | 0.0331 | 0.0297 | 0.0268 | 0.0242 | 0.0221 | 0.0202 | 0.0185 | 0.0170 | 0.0141 | 0.0118 | 0.0101 |
| **0.70** | 0.0752 | 0.0645 | 0.0560 | 0.0490 | 0.0433 | 0.0385 | 0.0345 | 0.0311 | 0.0282 | 0.0256 | 0.0234 | 0.0215 | 0.0198 | 0.0163 | 0.0137 | 0.0117 |
| **0.75** | 0.0869 | 0.0745 | 0.0645 | 0.0565 | 0.0499 | 0.0444 | 0.0397 | 0.0358 | 0.0324 | 0.0295 | 0.0269 | 0.0247 | 0.0228 | 0.0188 | 0.0157 | 0.0134 |
| **0.80** | 0.0995 | 0.0852 | 0.0738 | 0.0645 | 0.0570 | 0.0506 | 0.0453 | 0.0408 | 0.0370 | 0.0336 | 0.0307 | 0.0282 | 0.0259 | 0.0214 | 0.0179 | 0.0153 |
| **0.85** | 0.1130 | 0.0967 | 0.0837 | 0.0732 | 0.0645 | 0.0574 | 0.0513 | 0.0462 | 0.0418 | 0.0380 | 0.0347 | 0.0319 | 0.0293 | 0.0242 | 0.0203 | 0.0172 |
| **0.90** | 0.1276 | 0.1091 | 0.0943 | 0.0824 | 0.0726 | 0.0645 | 0.0577 | 0.0520 | 0.0470 | 0.0427 | 0.0390 | 0.0358 | 0.0329 | 0.0271 | 0.0228 | 0.0194 |
| **0.95** | 0.1433 | 0.1223 | 0.1057 | 0.0923 | 0.0813 | 0.0722 | 0.0645 | 0.0581 | 0.0525 | 0.0477 | 0.0436 | 0.0400 | 0.0368 | 0.0303 | 0.0254 | 0.0216 |
| **1.00** | 0.1601 | 0.1365 | 0.1178 | 0.1028 | 0.0905 | 0.0803 | 0.0718 | 0.0645 | 0.0584 | 0.0530 | 0.0484 | 0.0444 | 0.0408 | 0.0336 | 0.0282 | 0.0240 |
| **1.05** | 0.1780 | 0.1516 | 0.1307 | 0.1139 | 0.1002 | 0.0889 | 0.0794 | 0.0714 | 0.0645 | 0.0586 | 0.0535 | 0.0490 | 0.0451 | 0.0371 | 0.0311 | 0.0264 |
| **1.10** | 0.1972 | 0.1676 | 0.1444 | 0.1258 | 0.1106 | 0.0980 | 0.0875 | 0.0786 | 0.0711 | 0.0645 | 0.0589 | 0.0539 | 0.0496 | 0.0408 | 0.0342 | 0.0291 |
| **1.15** | 0.2177 | 0.1848 | 0.1589 | 0.1383 | 0.1215 | 0.1076 | 0.0961 | 0.0863 | 0.0779 | 0.0708 | 0.0645 | 0.0591 | 0.0544 | 0.0447 | 0.0374 | 0.0318 |
| **1.20** | 0.2396 | 0.2029 | 0.1744 | 0.1516 | 0.1330 | 0.1178 | 0.1051 | 0.0943 | 0.0852 | 0.0773 | 0.0705 | 0.0645 | 0.0593 | 0.0488 | 0.0408 | 0.0347 |
| **1.25** | 0.2629 | 0.2223 | 0.1907 | 0.1656 | 0.1452 | 0.1285 | 0.1145 | 0.1028 | 0.0927 | 0.0842 | 0.0767 | 0.0702 | 0.0645 | 0.0530 | 0.0444 | 0.0377 |
| **1.30** | 0.2877 | 0.2428 | 0.2080 | 0.1804 | 0.1581 | 0.1397 | 0.1245 | 0.1116 | 0.1007 | 0.0913 | 0.0832 | 0.0762 | 0.0700 | 0.0575 | 0.0481 | 0.0408 |
| **1.35** | 0.3142 | 0.2646 | 0.2263 | 0.1960 | 0.1716 | 0.1516 | 0.1349 | 0.1209 | 0.1091 | 0.0989 | 0.0901 | 0.0824 | 0.0757 | 0.0621 | 0.0520 | 0.0441 |
| **1.40** | 0.3424 | 0.2877 | 0.2456 | 0.2125 | 0.1858 | 0.1640 | 0.1459 | 0.1307 | 0.1178 | 0.1067 | 0.0972 | 0.0889 | 0.0816 | 0.0670 | 0.0560 | 0.0475 |
| **1.45** | 0.3725 | 0.3122 | 0.2661 | 0.2298 | 0.2007 | 0.1770 | 0.1574 | 0.1409 | 0.1269 | 0.1150 | 0.1047 | 0.0957 | 0.0878 | 0.0720 | 0.0602 | 0.0510 |
| **1.50** | 0.4047 | 0.3383 | 0.2877 | 0.2481 | 0.2165 | 0.1907 | 0.1694 | 0.1516 | 0.1365 | 0.1236 | 0.1124 | 0.1028 | 0.0943 | 0.0773 | 0.0645 | 0.0547 |
| **1.55** | 0.4391 | 0.3659 | 0.3105 | 0.2674 | 0.2330 | 0.2050 | 0.1820 | 0.1627 | 0.1464 | 0.1325 | 0.1205 | 0.1101 | 0.1010 | 0.0828 | 0.0691 | 0.0585 |
| **1.60** | 0.4759 | 0.3953 | 0.3347 | 0.2877 | 0.2503 | 0.2201 | 0.1952 | 0.1744 | 0.1568 | 0.1418 | 0.1290 | 0.1178 | 0.1080 | 0.0884 | 0.0738 | 0.0625 |
| **1.65** | 0.5154 | 0.4266 | 0.3603 | 0.3091 | 0.2686 | 0.2358 | 0.2089 | 0.1865 | 0.1676 | 0.1516 | 0.1377 | 0.1258 | 0.1153 | 0.0943 | 0.0786 | 0.0666 |
| **1.70** | 0.5578 | 0.4599 | 0.3873 | 0.3316 | 0.2877 | 0.2523 | 0.2233 | 0.1992 | 0.1789 | 0.1617 | 0.1469 | 0.1340 | 0.1229 | 0.1004 | 0.0837 | 0.0709 |

| Iph/IB Ia/IB | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 | 10.00 | 12.50 | 15.00 | 17.50 | 20.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.50** | 0.0051 | 0.0045 | 0.0039 | 0.0035 | 0.0031 | 0.0028 | 0.0025 | 0.0016 | 0.0011 | 0.0008 | 0.0006 |
| **0.55** | 0.0062 | 0.0054 | 0.0047 | 0.0042 | 0.0037 | 0.0034 | 0.0030 | 0.0019 | 0.0013 | 0.0010 | 0.0008 |
| **0.60** | 0.0074 | 0.0064 | 0.0056 | 0.0050 | 0.0045 | 0.0040 | 0.0036 | 0.0023 | 0.0016 | 0.0012 | 0.0009 |
| **0.65** | 0.0087 | 0.0075 | 0.0066 | 0.0059 | 0.0052 | 0.0047 | 0.0042 | 0.0027 | 0.0019 | 0.0014 | 0.0011 |
| **0.70** | 0.0101 | 0.0087 | 0.0077 | 0.0068 | 0.0061 | 0.0054 | 0.0049 | 0.0031 | 0.0022 | 0.0016 | 0.0012 |
| **0.75** | 0.0115 | 0.0101 | 0.0088 | 0.0078 | 0.0070 | 0.0063 | 0.0056 | 0.0036 | 0.0025 | 0.0018 | 0.0014 |
| **0.80** | 0.0131 | 0.0114 | 0.0101 | 0.0089 | 0.0079 | 0.0071 | 0.0064 | 0.0041 | 0.0028 | 0.0021 | 0.0016 |
| **0.85** | 0.0149 | 0.0129 | 0.0114 | 0.0101 | 0.0090 | 0.0080 | 0.0073 | 0.0046 | 0.0032 | 0.0024 | 0.0018 |
| **0.90** | 0.0167 | 0.0145 | 0.0127 | 0.0113 | 0.0101 | 0.0090 | 0.0081 | 0.0052 | 0.0036 | 0.0026 | 0.0020 |
| **0.95** | 0.0186 | 0.0162 | 0.0142 | 0.0126 | 0.0112 | 0.0101 | 0.0091 | 0.0058 | 0.0040 | 0.0030 | 0.0023 |
| **1.00** | 0.0206 | 0.0179 | 0.0157 | 0.0139 | 0.0124 | 0.0111 | 0.0101 | 0.0064 | 0.0045 | 0.0033 | 0.0025 |
| **1.05** | 0.0228 | 0.0198 | 0.0174 | 0.0154 | 0.0137 | 0.0123 | 0.0111 | 0.0071 | 0.0049 | 0.0036 | 0.0028 |
| **1.10** | 0.0250 | 0.0217 | 0.0191 | 0.0169 | 0.0151 | 0.0135 | 0.0122 | 0.0078 | 0.0054 | 0.0040 | 0.0030 |
| **1.15** | 0.0274 | 0.0238 | 0.0209 | 0.0185 | 0.0165 | 0.0148 | 0.0133 | 0.0085 | 0.0059 | 0.0043 | 0.0033 |
| **1.20** | 0.0298 | 0.0259 | 0.0228 | 0.0201 | 0.0179 | 0.0161 | 0.0145 | 0.0093 | 0.0064 | 0.0047 | 0.0036 |
| **1.25** | 0.0324 | 0.0282 | 0.0247 | 0.0219 | 0.0195 | 0.0175 | 0.0157 | 0.0101 | 0.0070 | 0.0051 | 0.0039 |
| **1.30** | 0.0351 | 0.0305 | 0.0268 | 0.0237 | 0.0211 | 0.0189 | 0.0170 | 0.0109 | 0.0075 | 0.0055 | 0.0042 |
| **1.35** | 0.0379 | 0.0329 | 0.0289 | 0.0255 | 0.0228 | 0.0204 | 0.0184 | 0.0117 | 0.0081 | 0.0060 | 0.0046 |
| **1.40** | 0.0408 | 0.0355 | 0.0311 | 0.0275 | 0.0245 | 0.0220 | 0.0198 | 0.0126 | 0.0087 | 0.0064 | 0.0049 |
| **1.45** | 0.0439 | 0.0381 | 0.0334 | 0.0295 | 0.0263 | 0.0236 | 0.0212 | 0.0135 | 0.0094 | 0.0069 | 0.0053 |
| **1.50** | 0.0470 | 0.0408 | 0.0358 | 0.0316 | 0.0282 | 0.0252 | 0.0228 | 0.0145 | 0.0101 | 0.0074 | 0.0056 |
| **1.55** | 0.0503 | 0.0437 | 0.0383 | 0.0338 | 0.0301 | 0.0270 | 0.0243 | 0.0155 | 0.0107 | 0.0079 | 0.0060 |
| **1.60** | 0.0537 | 0.0466 | 0.0408 | 0.0361 | 0.0321 | 0.0288 | 0.0259 | 0.0165 | 0.0114 | 0.0084 | 0.0064 |
| **1.65** | 0.0572 | 0.0496 | 0.0435 | 0.0384 | 0.0342 | 0.0306 | 0.0276 | 0.0176 | 0.0122 | 0.0089 | 0.0068 |
| **1.70** | 0.0608 | 0.0527 | 0.0462 | 0.0408 | 0.0363 | 0.0325 | 0.0293 | 0.0187 | 0.0129 | 0.0095 | 0.0073 |

(1) *Ia is the permissible current for the cable.*

# Thermal Overload for Cables
ANSI Code 49RMS
Trip Curves

## Curves for Initial Heat Rise = 100%

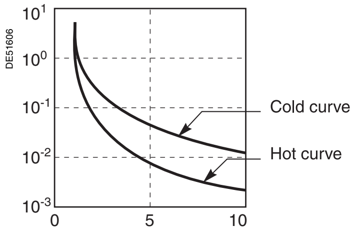
| **Iph/IB Ia/IB** | **1.15** | **1.20** | **1.25** | **1.30** | **1.35** | **1.40** | **1.45** | **1.50** | **1.55** | **1.60** | **1.65** | **1.70** | **1.75** | **1.80** | **1.85** | **1.90** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.10** | 1.0531 | 0.6487 | 0.4673 | 0.3629 | 0.2948 | 0.2469 | 0.2113 | 0.1839 | 0.1622 | 0.1446 | 0.1300 | 0.1178 | 0.1074 | 0.0984 | 0.0907 | 0.0839 |
| **1.15** |  | 1.3203 | 0.8518 | 0.6300 | 0.4977 | 0.4094 | 0.3460 | 0.2984 | 0.2613 | 0.2316 | 0.2073 | 0.1871 | 0.1700 | 0.1555 | 0.1429 | 0.1319 |
| **1.20** |  |  | 1.5243 | 1.0152 | 0.7656 | 0.6131 | 0.5093 | 0.4339 | 0.3765 | 0.3314 | 0.2950 | 0.2650 | 0.2400 | 0.2187 | 0.2004 | 0.1846 |
| **1.25** |  |  |  | 1.6886 | 1.1517 | 0.8817 | 0.7138 | 0.5978 | 0.5126 | 0.4472 | 0.3954 | 0.3533 | 0.3185 | 0.2892 | 0.2642 | 0.2427 |
| **1.30** |  |  |  |  | 1.8258 | 1.2685 | 0.9831 | 0.8030 | 0.6772 | 0.5840 | 0.5118 | 0.4543 | 0.4073 | 0.3682 | 0.3352 | 0.3070 |
| **1.35** |  |  |  |  |  | 1.9433 | 1.3705 | 1.0729 | 0.8830 | 0.7492 | 0.6491 | 0.5713 | 0.5088 | 0.4576 | 0.4148 | 0.3785 |
| **1.40** |  |  |  |  |  |  | 2.0460 | 1.4610 | 1.1536 | 0.9555 | 0.8149 | 0.7092 | 0.6263 | 0.5596 | 0.5047 | 0.4586 |
| **1.45** |  |  |  |  |  |  |  | 2.1371 | 1.5422 | 1.2267 | 1.0218 | 0.8755 | 0.7647 | 0.6776 | 0.6072 | 0.5489 |
| **1.50** |  |  |  |  |  |  |  |  | 2.2188 | 1.6159 | 1.2935 | 1.0829 | 0.9316 | 0.8165 | 0.7257 | 0.6519 |
| **1.55** |  |  |  |  |  |  |  |  |  | 2.2930 | 1.6832 | 1.3550 | 1.1394 | 0.9838 | 0.8650 | 0.7708 |
| **1.60** |  |  |  |  |  |  |  |  |  |  | 2.3609 | 1.7452 | 1.4121 | 1.1921 | 1.0327 | 0.9106 |
| **1.65** |  |  |  |  |  |  |  |  |  |  |  | 2.4233 | 1.8027 | 1.4652 | 1.2415 | 1.0787 |
| **1.70** |  |  |  |  |  |  |  |  |  |  |  |  | 2.4813 | 1.8563 | 1.5150 | 1.2879 |

| **Iph/IB Ia/IB** | **1.95** | **2.00** | **2.20** | **2.40** | **2.60** | **2.80** | **3.00** | **3.20** | **3.40** | **3.60** | **3.80** | **4.00** | **4.20** | **4.40** | **4.60** | **4.80** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.10** | 0.0779 | 0.0726 | 0.0562 | 0.0451 | 0.0371 | 0.0312 | 0.0266 | 0.0230 | 0.0201 | 0.0177 | 0.0157 | 0.0141 | 0.0127 | 0.0115 | 0.0105 | 0.0096 |
| **1.15** | 0.1223 | 0.1137 | 0.0877 | 0.0702 | 0.0576 | 0.0483 | 0.0411 | 0.0355 | 0.0310 | 0.0273 | 0.0243 | 0.0217 | 0.0196 | 0.0177 | 0.0161 | 0.0147 |
| **1.20** | 0.1708 | 0.1586 | 0.1217 | 0.0970 | 0.0795 | 0.0665 | 0.0566 | 0.0488 | 0.0426 | 0.0375 | 0.0333 | 0.0298 | 0.0268 | 0.0243 | 0.0221 | 0.0202 |
| **1.25** | 0.2240 | 0.2076 | 0.1584 | 0.1258 | 0.1028 | 0.0858 | 0.0729 | 0.0628 | 0.0547 | 0.0482 | 0.0428 | 0.0382 | 0.0344 | 0.0311 | 0.0283 | 0.0259 |
| **1.30** | 0.2826 | 0.2614 | 0.1981 | 0.1566 | 0.1276 | 0.1063 | 0.0902 | 0.0776 | 0.0676 | 0.0594 | 0.0527 | 0.0471 | 0.0424 | 0.0383 | 0.0348 | 0.0318 |
| **1.35** | 0.3474 | 0.3204 | 0.2410 | 0.1897 | 0.1541 | 0.1281 | 0.1085 | 0.0932 | 0.0811 | 0.0713 | 0.0632 | 0.0564 | 0.0507 | 0.0458 | 0.0417 | 0.0380 |
| **1.40** | 0.4194 | 0.3857 | 0.2877 | 0.2253 | 0.1823 | 0.1512 | 0.1278 | 0.1097 | 0.0953 | 0.0837 | 0.0741 | 0.0661 | 0.0594 | 0.0537 | 0.0488 | 0.0445 |
| **1.45** | 0.4999 | 0.4581 | 0.3384 | 0.2635 | 0.2125 | 0.1758 | 0.1483 | 0.1271 | 0.1103 | 0.0967 | 0.0856 | 0.0763 | 0.0686 | 0.0619 | 0.0562 | 0.0513 |
| **1.50** | 0.5907 | 0.5390 | 0.3938 | 0.3046 | 0.2446 | 0.2018 | 0.1699 | 0.1454 | 0.1260 | 0.1104 | 0.0976 | 0.0870 | 0.0781 | 0.0705 | 0.0640 | 0.0584 |
| **1.55** | 0.6940 | 0.6302 | 0.4545 | 0.3491 | 0.2790 | 0.2295 | 0.1928 | 0.1646 | 0.1425 | 0.1247 | 0.1102 | 0.0982 | 0.0881 | 0.0795 | 0.0721 | 0.0657 |
| **1.60** | 0.8134 | 0.7340 | 0.5213 | 0.3971 | 0.3159 | 0.2589 | 0.2169 | 0.1849 | 0.1599 | 0.1398 | 0.1234 | 0.1098 | 0.0984 | 0.0888 | 0.0805 | 0.0734 |
| **1.65** | 0.9536 | 0.8537 | 0.5952 | 0.4492 | 0.3553 | 0.2901 | 0.2425 | 0.2063 | 0.1781 | 0.1555 | 0.1372 | 0.1220 | 0.1093 | 0.0985 | 0.0893 | 0.0814 |
| **1.70** | 1.1221 | 0.9943 | 0.6776 | 0.5059 | 0.3977 | 0.3234 | 0.2695 | 0.2288 | 0.1972 | 0.1720 | 0.1516 | 0.1347 | 0.1206 | 0.1086 | 0.0984 | 0.0897 |

| **Iph/IB Ia/IB** | **5.00** | **5.50** | **6.00** | **6.50** | **7.00** | **7.50** | **8.00** | **8.50** | **9.00** | **9.50** | **10.00** | **12.50** | **15.00** | **17.50** | **20.00** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.10** | 0.0088 | 0.0072 | 0.0060 | 0.0051 | 0.0044 | 0.0038 | 0.0033 | 0.0030 | 0.0026 | 0.0024 | 0.0021 | 0.0014 | 0.0009 | 0.0007 | 0.0005 |
| **1.15** | 0.0135 | 0.0111 | 0.0093 | 0.0078 | 0.0067 | 0.0059 | 0.0051 | 0.0045 | 0.0040 | 0.0036 | 0.0033 | 0.0021 | 0.0014 | 0.0011 | 0.0008 |
| **1.20** | 0.0185 | 0.0152 | 0.0127 | 0.0107 | 0.0092 | 0.0080 | 0.0070 | 0.0062 | 0.0055 | 0.0049 | 0.0045 | 0.0028 | 0.0020 | 0.0014 | 0.0011 |
| **1.25** | 0.0237 | 0.0194 | 0.0162 | 0.0137 | 0.0118 | 0.0102 | 0.0090 | 0.0079 | 0.0071 | 0.0063 | 0.0057 | 0.0036 | 0.0025 | 0.0018 | 0.0014 |
| **1.30** | 0.0292 | 0.0239 | 0.0199 | 0.0169 | 0.0145 | 0.0126 | 0.0110 | 0.0097 | 0.0087 | 0.0078 | 0.0070 | 0.0045 | 0.0031 | 0.0023 | 0.0017 |
| **1.35** | 0.0349 | 0.0285 | 0.0238 | 0.0201 | 0.0173 | 0.0150 | 0.0131 | 0.0116 | 0.0103 | 0.0093 | 0.0083 | 0.0053 | 0.0037 | 0.0027 | 0.0021 |
| **1.40** | 0.0408 | 0.0334 | 0.0278 | 0.0235 | 0.0202 | 0.0175 | 0.0154 | 0.0136 | 0.0121 | 0.0108 | 0.0097 | 0.0062 | 0.0043 | 0.0031 | 0.0024 |
| **1.45** | 0.0470 | 0.0384 | 0.0320 | 0.0271 | 0.0232 | 0.0202 | 0.0177 | 0.0156 | 0.0139 | 0.0124 | 0.0112 | 0.0071 | 0.0049 | 0.0036 | 0.0028 |
| **1.50** | 0.0535 | 0.0437 | 0.0364 | 0.0308 | 0.0264 | 0.0229 | 0.0200 | 0.0177 | 0.0157 | 0.0141 | 0.0127 | 0.0081 | 0.0056 | 0.0041 | 0.0031 |
| **1.55** | 0.0602 | 0.0491 | 0.0409 | 0.0346 | 0.0297 | 0.0257 | 0.0225 | 0.0199 | 0.0177 | 0.0158 | 0.0143 | 0.0091 | 0.0063 | 0.0046 | 0.0035 |
| **1.60** | 0.0672 | 0.0548 | 0.0456 | 0.0386 | 0.0330 | 0.0286 | 0.0251 | 0.0221 | 0.0197 | 0.0176 | 0.0159 | 0.0101 | 0.0070 | 0.0051 | 0.0039 |
| **1.65** | 0.0745 | 0.0607 | 0.0505 | 0.0427 | 0.0365 | 0.0317 | 0.0277 | 0.0245 | 0.0218 | 0.0195 | 0.0176 | 0.0112 | 0.0077 | 0.0057 | 0.0043 |
| **1.70** | 0.0820 | 0.0668 | 0.0555 | 0.0469 | 0.0402 | 0.0348 | 0.0305 | 0.0269 | 0.0239 | 0.0214 | 0.0193 | 0.0122 | 0.0085 | 0.0062 | 0.0047 |

# Thermal Overload for Capacitors
ANSI Code 49RMS

*Protection of equipment against thermal damage due to overloads.*



*Tripping curves.*

## Description

This function is used to protect capacitor banks with or without harmonic filters against overloads, based on the measurement of the current drawn.

The current measured by the thermal protection is an RMS 3-phase current that factors harmonics up to the13th.

The highest current of the three phases Ia, Ib, and Ic, subsequently called phase current Iph, is used to calculate the heat rise:

$$Iph = \max(Ia, Ib, Ic)$$

**Taking capacitor step ratio into account**

When the number of steps (>1) and capacitor step ratio are set in the particular characteristics, the thermal overload protection function takes into account the participation of each step in the calculation of heat rise.

The rated current of step x (IBgx) is equal to the fraction of current that the step represents in relation to the rated current of the capacitor bank (IB).

$$IBgx = \frac{Kgx}{\sum_{x=1}^{n} Kgx} IB$$

where IB is the rated current of the capacitor bank
x is the step number
n is the total number of steps, between 2 and 4
Kgx is the capacitor step ratio value of step x

The rated current of the sequence of steps (IBseq) is calculated. It is the sum of the rated currents (IBgx) of the steps closed during the sequence.

$$IBseq = \sum_{x=1}^{n} p(x) IBgx$$

where x is the step number
n is the total number of steps, between 2 and 4
p(x) is the position of the step x:
- p(x) = 1 when the step switch x is closed
- p(x) = 0 when the step switch x is open.

The heat rise is proportional to the square of the current in relation to the rated current of the sequence. Under steady state conditions, it is equal to:

$$E = \left(\frac{Iph}{Ibseq}\right)^2 \times 100 \quad \text{as a\%}$$

If the closed positions of the steps are not acquired or if the number of steps set in the particular characteristics is 1, the rated current of the sequences is equal to the rated current of the capacitor bank. In such cases, the heat rise is proportional to the drawn current in relation to the rated current of the capacitor bank. Under steady state conditions, it is equal to:

$$E = \left(\frac{Iph}{Ib}\right)^2 \times 100 \quad \text{as a\%}$$

# Thermal Overload for Capacitors
ANSI Code 49RMS

**Operation curve**
The protection function gives a trip command when the current drawn is greater than the overload current, with respect to the rated current of the sequence.

Tripping time is set by assigning a hot tripping time to a setting current. This setting is used to calculate a time factor:

$$C = \frac{1}{\ln\left(\frac{\left(\frac{Is}{IB}\right)^2 - 1}{\left(\frac{Is}{IB}\right)^2 - \left(\frac{Itrip}{IB}\right)^2}\right)}$$ where ln: natural logarithm.

The tripping time with an initial heat rise of 0% is then given by:

$$t = C \times \ln\left(\frac{\left(\frac{Iph}{IBseq}\right)^2}{\left(\frac{Iph}{Ibseq}\right)^2 - \left(\frac{Itrip}{Ibseq}\right)^2}\right) \times Ts$$ where ln: natural logarithm.

**= k x Ts**

The tripping time with an intial heat rise of 100% is then given by:

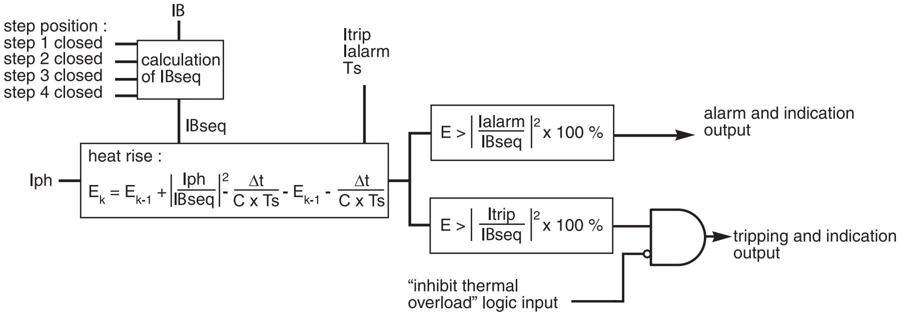
$$t = C \times \ln\left(\frac{\left(\frac{Iph}{Ibseq}\right)^2 - 1}{\left(\frac{Iph}{Ibseq}\right)^2 - \left(\frac{Itrip}{Ibseq}\right)^2}\right) \times Ts$$ where ln: natural logarithm.

**= k x Ts**

The tripping curve tables give the values of k for an inital heat rise from 0% to 100%. The current heat rise is saved in the event of an auxiliary power failure.

## Block Diagram

DE51555


IB
step position :
step 1 closed
step 2 closed
step 3 closed
step 4 closed
calculation of IBseq
IBseq
Itrip
Ialarm
Ts
Iph
heat rise :
$E_k = E_{k-1} + \left|\frac{Iph}{IBseq}\right|^2 \frac{\Delta t}{C \times Ts} - E_{k-1} \frac{\Delta t}{C \times Ts}$
$E > \left|\frac{Ialarm}{IBseq}\right|^2 \times 100\ \%$
alarm and indication output
$E > \left|\frac{Itrip}{IBseq}\right|^2 \times 100\ \%$
tripping and indication output
"inhibit thermal overload" logic input

# Thermal Overload for Capacitors
ANSI Code 49RMS

## User Information

The following information is available for the user:

- heat rise
- time before tripping (with constant current).

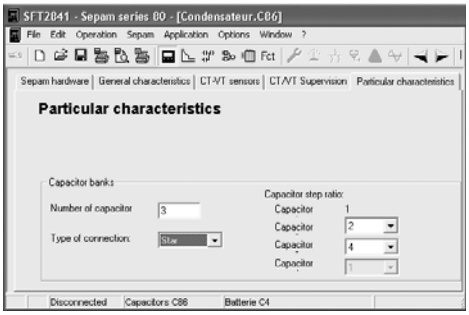
## Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Alarm Current Ialarm** | | | | |
| Setting range | 1.05 to 1.70 IB | | | |
| Accuracy (1) | ±2% | | | |
| Resolution | 1 A | | | |
| **Tripping Current Itrip** | | | | |
| Setting range | 1.05 to 1.70 IB | | | |
| Accuracy (1) | ±2% | | | |
| Resolution | 1 A | | | |
| **Setting Current Is** | | | | |
| Setting range | 1.02 Itrip to 2 IB | | | |
| Accuracy (1) | ±2% | | | |
| Resolution | 1 A | | | |
| **Setting Time Ts** | | | | |
| Setting range | 1 to 2000 minutes (range varies depending on the tripping and setting currents) | | | |
| Resolution | 1 mn | | | |
| **Characteristic Times** | | | | |
| Operation time accuracy | ±2% or ±2 s | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P49RMS_1_101 | ■ | ■ | |
| Protection blocking | P49RMS_1_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Delayed output | P49RMS _1_3 | ■ | ■ | ■ |
| Alarm | P49RMS _1_10 | ■ | ■ | ■ |
| Block closing | P49RMS _1_11 | ■ | ■ | ■ |
| Protection blocked | P49RMS _1_16 | ■ | ■ | |
| Hot state | P49RMS _1_18 | ■ | ■ | |

***(1)** Under reference conditions (IEC 60255-6).*

# Thermal Overload for Capacitors
## ANSI Code 49RMS

PE50424


SFT2041 - Sepam series 80 - [Condensateur.C86]
File Edit Operation Sepam Application Options Window ?
Fct
Sepam hardware
General characteristics
CT-VT sensors
CT/VT Supervision
Particular characteristics
Disconnected
Capacitors C86
Batterie C4

Particular characteristics

Capacitor banks

Number of capacitor: 3

Type of connection: Star

Capacitor step ratio:
Capacitor 1
Capacitor 2
Capacitor 4
Capacitor 1

*Parameter setting of capacitor bank step ratio.*

### Example

Given a 350 kVAR capacitor bank with three steps, and no harmonic filters, for a voltage of 2 kV. The capacitor step ratio is 1.2.2.

The rated current of the capacitor bank is:
IB = -31 °FQ /(√3 $V_{LLN}$ )= 350000 (√3  x 2000) = 101 A

According to the manufacturer data, this capacitor bank can operate continuously with an overload current of 120% IB and for 20 minutes with an overload of 140% IB.

The protection settings are:
Itrip = 120% IB = 121 A
Is = 140% IB = 141 A
Ts = 20 min.

**Steps 1 and 2 closed**

Steps 1 and 2 are closed in the sequence in progress. The sequence current is:

$$IBseq = \frac{1+2+0}{1+2+2} \times IB = 61\ A$$

For a current of 125% IBseq = 76 A, and an initial heat rise of 100%, the value of k in the tripping curve tables is: k = 2.486.

The tripping time is:
**t = k x Ts = 2.486 x 20 ≈ 50 mn**

**All the steps closed**

When all the steps are closed, the sequence current is the rated current of the capacitor bank:

$$IBseq = \frac{1+2+2}{1+2+2} \times IB = 101\ A$$

For a current of 140% IBseq = 141 A, and an initial heat rise of 0%, the value of k in the tripping curve tables is: k = 2.164.

The tripping time is:
**t = k x Ts = 2.164 x 20 ≈ 43 mn**

The table below summarizes the rated sequence current, the tripping current and examples of tripping times for overload currents of 125% IB and 140% IB, for initial heat rises of 0% and 100%.

| Closed Step Numbers | | | IBseq (A) | Itrip (A) | 125% IBseq | | | 140% IBseq | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Iph (A) | Tripping time (mn) | | Iph (A) | Tripping time (mn) | |
| 1 | 2 | 3 | | | | 0% | 100% | | 0% | 100% |
| ■ | - | - | $\frac{+0+0}{+2+2} \times IB = 20$ | 24 | 25 | 83 | 50 | 28 | 43 | 20 |
| ■ | ■ | - | $\frac{+2+0}{+2+2} \times IB = 61$ | 73 | 76 | 83 | 50 | 85 | 43 | 20 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| - | ■ | ■ | $\frac{+ 2 + 2}{+ 2 + 2} \times IB = 81$ | 97 | 101 | 83 | 50 | 113 | 43 | 20 |
| | | | | | | | | | | |
| ■ | ■ | ■ | $\frac{1 + 2 + 2}{1 + 2 + 2} \times IB = 101$ | 121 | 126 | 83 | 50 | 141 | 43 | 20 |
| | | | | | | | | | | |

### Curves for Initial Heat Rise = 0%

**Is = 1.2 IB**

| **Iph/IBseq** | **1.10** | **1.15** | **1.20** | **1.25** | **1.30** | **1.35** | **1.40** | **1.45** | **1.50** | **1.55** | **1.60** | **1.65** | **1.70** | **1.75** | **1.80** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | | |
| **1.05** | 9.1282 | 6.7632 | 5.4705 | 4.6108 | 3.9841 | 3.5018 | 3.1171 | 2.8020 | 2.5389 | 2.3157 | 2.1239 | 1.9574 | 1.8115 | 1.6828 | 1.5683 |
| **1.10** | | 3.7989 | 2.8277 | 2.2954 | 1.9404 | 1.6809 | 1.4809 | 1.3209 | 1.1896 | 1.0798 | 0.9865 | 0.9061 | 0.8362 | 0.7749 | 0.7207 |
| **1.15** | | | 1.8980 | 1.4189 | 1.1556 | 0.9796 | 0.8507 | 0.7510 | 0.6712 | 0.6056 | 0.5506 | 0.5037 | 0.4634 | 0.4282 | 0.3973 |

**Is = 1.2 IB**

| **Iph/IBseq** | **1.85** | **1.90** | **1.95** | **2.00** | **2.20** | **2.40** | **2.60** | **2.80** | **3.00** | **3.20** | **3.40** | **3.60** | **3.80** | **4.00** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | |
| **1.05** | 1.4660 | 1.3741 | 1.2911 | 1.2158 | 0.9747 | 0.8011 | 0.6713 | 0.5714 | 0.4927 | 0.4295 | 0.3779 | 0.3352 | 0.2995 | 0.2692 |
| **1.10** | 0.6725 | 0.6293 | 0.5905 | 0.5554 | 0.4435 | 0.3635 | 0.3040 | 0.2584 | 0.2226 | 0.1939 | 0.1704 | 0.1511 | 0.1349 | 0.1212 |
| **1.15** | 0.3699 | 0.3456 | 0.3237 | 0.3040 | 0.2417 | 0.1976 | 0.1649 | 0.1399 | 0.1204 | 0.1047 | 0.0920 | 0.0815 | 0.0728 | 0.0653 |

**Is = 1.3 IB**

| **Iph/IBseq** | **1.10** | **1.15** | **1.20** | **1.25** | **1.30** | **1.35** | **1.40** | **1.45** | **1.50** | **1.55** | **1.60** | **1.65** | **1.70** | **1.75** | **1.80** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | | |
| **1.05** | 15.0540 | 11.1530 | 9.0217 | 7.6039 | 6.5703 | 5.7750 | 5.1405 | 4.6210 | 4.1871 | 3.8189 | 3.5027 | 3.2281 | 2.9875 | 2.7752 | 2.5864 |
| **1.10** | | 6.7905 | 5.0545 | 4.1030 | 3.4684 | 3.0047 | 2.6470 | 2.3611 | 2.1265 | 1.9301 | 1.7633 | 1.6197 | 1.4948 | 1.3852 | 1.2883 |
| **1.15** | | | 3.9779 | 2.9738 | 2.4220 | 2.0530 | 1.7829 | 1.5740 | 1.4067 | 1.2692 | 1.1539 | 1.0557 | 0.9711 | 0.8974 | 0.8327 |
| **1.20** | | | | 2.5077 | 1.8824 | 1.5378 | 1.3070 | 1.1375 | 1.0063 | 0.9010 | 0.8143 | 0.7415 | 0.6794 | 0.6257 | 0.5790 |
| **1.25** | | | | | 1.5305 | 1.1532 | 0.9449 | 0.8050 | 0.7021 | 0.6223 | 0.5582 | 0.5052 | 0.4607 | 0.4227 | 0.3898 |

**Is = 1.3 IB**

| **Iph/IBseq** | **1.85** | **1.90** | **1.95** | **2.00** | **2.20** | **2.40** | **2.60** | **2.80** | **3.00** | **3.20** | **3.40** | **3.60** | **3.80** | **4.00** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | |
| **1.05** | 2.4177 | 2.2661 | 2.1292 | 2.0051 | 1.6074 | 1.3211 | 1.1071 | 0.9424 | 0.8126 | 0.7084 | 0.6233 | 0.5529 | 0.4939 | 0.4440 |
| **1.10** | 1.2021 | 1.1249 | 1.0555 | 0.9927 | 0.7927 | 0.6498 | 0.5435 | 0.4619 | 0.3979 | 0.3465 | 0.3047 | 0.2701 | 0.2412 | 0.2167 |
| **1.15** | 0.7753 | 0.7242 | 0.6785 | 0.6372 | 0.5066 | 0.4141 | 0.3456 | 0.2933 | 0.2523 | 0.2195 | 0.1929 | 0.1709 | 0.1525 | 0.1370 |
| **1.20** | 0.5378 | 0.5013 | 0.4688 | 0.4396 | 0.3478 | 0.2834 | 0.2360 | 0.1999 | 0.1717 | 0.1493 | 0.1310 | 0.1160 | 0.1035 | 0.0929 |
| **1.25** | 0.3611 | 0.3358 | 0.3134 | 0.2933 | 0.2309 | 0.1874 | 0.1557 | 0.1316 | 0.1129 | 0.0981 | 0.0860 | 0.0761 | 0.0678 | 0.0609 |

**Is = 1.4 Ib**

| **Iph/IBseq** | **1.10** | **1.15** | **1.20** | **1.25** | **1.30** | **1.35** | **1.40** | **1.45** | **1.50** | **1.55** | **1.60** | **1.65** | **1.70** | **1.75** | **1.80** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | | |
| **1.05** | 21.4400 | 15.8850 | 12.8490 | 10.8300 | 9.3578 | 8.2251 | 7.3214 | 6.5815 | 5.9634 | 5.4391 | 4.9887 | 4.5976 | 4.2550 | 3.9525 | 3.6837 |
| **1.10** | | 9.9827 | 7.4306 | 6.0317 | 5.0988 | 4.4171 | 3.8914 | 3.4710 | 3.1261 | 2.8375 | 2.5922 | 2.3811 | 2.1975 | 2.0364 | 1.8939 |
| **1.15** | | | 6.1214 | 4.5762 | 3.7270 | 3.1593 | 2.7435 | 2.4222 | 2.1647 | 1.9531 | 1.7757 | 1.6246 | 1.4944 | 1.3810 | 1.2813 |
| **1.20** | | | | 4.1525 | 3.1170 | 2.5464 | 2.1642 | 1.8836 | 1.6664 | 1.4920 | 1.3483 | 1.2278 | 1.1249 | 1.0361 | 0.9587 |
| **1.25** | | | | | 2.9310 | 2.2085 | 1.8095 | 1.5416 | 1.3446 | 1.1918 | 1.0689 | 0.9676 | 0.8823 | 0.8095 | 0.7466 |
| **1.30** | | | | | | 2.0665 | 1.5627 | 1.2839 | 1.0964 | 0.9582 | 0.8508 | 0.7643 | 0.6929 | 0.6327 | 0.5813 |
| **1.35** | | | | | | | 1.3673 | 1.0375 | 0.8546 | 0.7314 | 0.6404 | 0.5696 | 0.5125 | 0.4653 | 0.4254 |

**Is = 1.4 Ib**

| **Iph/IBseq** | **1.85** | **1.90** | **1.95** | **2.00** | **2.20** | **2.40** | **2.60** | **2.80** | **3.00** | **3.20** | **3.40** | **3.60** | **3.80** | **4.00** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | |
| **1.05** | 3.4434 | 3.2275 | 3.0325 | 2.8557 | 2.2894 | 1.8816 | 1.5768 | 1.3422 | 1.1573 | 1.0089 | 0.8877 | 0.7874 | 0.7034 | 0.6323 |
| **1.10** | 1.7672 | 1.6537 | 1.5516 | 1.4593 | 1.1654 | 0.9552 | 0.7989 | 0.6791 | 0.5849 | 0.5094 | 0.4479 | 0.3970 | 0.3545 | 0.3186 |
| **1.15** | 1.1931 | 1.1145 | 1.0440 | 0.9805 | 0.7796 | 0.6372 | 0.5318 | 0.4513 | 0.3882 | 0.3378 | 0.2968 | 0.2629 | 0.2346 | 0.2107 |
| **1.20** | 0.8906 | 0.8302 | 0.7763 | 0.7279 | 0.5760 | 0.4692 | 0.3907 | 0.3310 | 0.2844 | 0.2472 | 0.2170 | 0.1921 | 0.1714 | 0.1538 |
| **1.25** | 0.6916 | 0.6432 | 0.6002 | 0.5618 | 0.4421 | 0.3589 | 0.2981 | 0.2521 | 0.2163 | 0.1878 | 0.1647 | 0.1457 | 0.1299 | 0.1165 |
| **1.30** | 0.5367 | 0.4977 | 0.4634 | 0.4328 | 0.3386 | 0.2738 | 0.2268 | 0.1914 | 0.1640 | 0.1422 | 0.1246 | 0.1102 | 0.0981 | 0.0880 |
| **1.35** | 0.3913 | 0.3617 | 0.3358 | 0.3129 | 0.2431 | 0.1957 | 0.1617 | 0.1361 | 0.1164 | 0.1009 | 0.0883 | 0.0780 | 0.0694 | 0.0622 |

## Curves for Initial Heat Rise = 0%

**Is = 2 IB**

| Iph/IBseq<br>Itrip/IBseq | 1.10 | 1.15 | 1.20 | 1.25 | 1.30 | 1.35 | 1.40 | 1.45 | 1.50 | 1.55 | 1.60 | 1.65 | 1.70 | 1.75 | 1.80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.05** | 69.6380 | 51.5950 | 41.7340 | 35.1750 | 30.3940 | 26.7150 | 23.7800 | 21.3760 | 19.3690 | 17.6660 | 16.2030 | 14.9330 | 13.8200 | 12.8380 | 11.9650 |
| **1.10** | | 33.9580 | 25.2760 | 20.5180 | 17.3440 | 15.0260 | 13.2370 | 11.8070 | 10.6340 | 9.6521 | 8.8176 | 8.0995 | 7.4750 | 6.9270 | 6.4425 |
| **1.15** | | | 22.0350 | 16.4730 | 13.4160 | 11.3720 | 9.8756 | 8.7189 | 7.7922 | 7.0303 | 6.3916 | 5.8479 | 5.3792 | 4.9710 | 4.6123 |
| **1.20** | | | | 16.0520 | 12.0490 | 9.8435 | 8.3659 | 7.2814 | 6.4415 | 5.7674 | 5.2122 | 4.7460 | 4.3485 | 4.0053 | 3.7060 |
| **1.25** | | | | | 12.4460 | 9.3782 | 7.6840 | 6.5465 | 5.7100 | 5.0610 | 4.5392 | 4.1087 | 3.7467 | 3.4375 | 3.1703 |
| **1.30** | | | | | | 10.0300 | 7.5843 | 6.2313 | 5.3211 | 4.6505 | 4.1294 | 3.7096 | 3.3629 | 3.0708 | 2.8210 |
| **1.35** | | | | | | | 8.2921 | 6.2917 | 5.1827 | 4.4353 | 3.8838 | 3.4544 | 3.1081 | 2.8215 | 2.5799 |
| **1.40** | | | | | | | | 6.9790 | 5.3124 | 4.3868 | 3.7619 | 3.3000 | 2.9399 | 2.6491 | 2.4081 |
| **1.50** | | | | | | | | | | 5.1152 | 3.9169 | 3.2491 | 2.7969 | 2.4617 | 2.1997 |
| **1.60** | | | | | | | | | | | | 3.8403 | 2.9564 | 2.4625 | 2.1271 |
| **1.70** | | | | | | | | | | | | | | 2.8932 | 2.2383 |

**Is = 2 IB**

| Iph/IBseq<br>Itrip/IBseq | 1.85 | 1.90 | 1.95 | 2.00 | 2.20 | 2.40 | 2.60 | 2.80 | 3.00 | 3.20 | 3.40 | 3.60 | 3.80 | 4.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.05** | 11.1840 | 10.4830 | 9.8495 | 9.2753 | 7.4358 | 6.1115 | 5.1214 | 4.3594 | 3.7590 | 3.2768 | 2.8832 | 2.5574 | 2.2846 | 2.0537 |
| **1.10** | 6.0114 | 5.6254 | 5.2781 | 4.9642 | 3.9642 | 3.2494 | 2.7177 | 2.3099 | 1.9896 | 1.7328 | 1.5235 | 1.3506 | 1.2059 | 1.0836 |
| **1.15** | 4.2947 | 4.0117 | 3.7581 | 3.5295 | 2.8064 | 2.2936 | 1.9142 | 1.6245 | 1.3975 | 1.2159 | 1.0683 | 0.9464 | 0.8446 | 0.7586 |
| **1.20** | 3.4426 | 3.2091 | 3.0008 | 2.8138 | 2.2265 | 1.8138 | 1.5104 | 1.2795 | 1.0993 | 0.9555 | 0.8388 | 0.7426 | 0.6624 | 0.5946 |
| **1.25** | 2.9368 | 2.7311 | 2.5486 | 2.3855 | 1.8775 | 1.5240 | 1.2659 | 1.0704 | 0.9184 | 0.7974 | 0.6994 | 0.6187 | 0.5515 | 0.4949 |
| **1.30** | 2.6048 | 2.4157 | 2.2489 | 2.1007 | 1.6433 | 1.3288 | 1.1007 | 0.9289 | 0.7958 | 0.6901 | 0.6047 | 0.5346 | 0.4762 | 0.4271 |
| **1.35** | 2.3729 | 2.1935 | 2.0365 | 1.8978 | 1.4745 | 1.1871 | 0.9804 | 0.8257 | 0.7061 | 0.6116 | 0.5354 | 0.4730 | 0.4210 | 0.3774 |
| **1.40** | 2.2046 | 2.0301 | 1.8787 | 1.7459 | 1.3461 | 1.0785 | 0.8878 | 0.7459 | 0.6369 | 0.5509 | 0.4817 | 0.4252 | 0.3782 | 0.3388 |
| **1.50** | 1.9875 | 1.8112 | 1.6620 | 1.5337 | 1.1600 | 0.9190 | 0.7509 | 0.6276 | 0.5337 | 0.4603 | 0.4016 | 0.3538 | 0.3143 | 0.2812 |
| **1.60** | 1.8779 | 1.6825 | 1.5240 | 1.3920 | 1.0256 | 0.8008 | 0.6484 | 0.5386 | 0.4560 | 0.3920 | 0.3411 | 0.2998 | 0.2659 | 0.2376 |
| **1.70** | 1.8713 | 1.6215 | 1.4355 | 1.2893 | 0.9143 | 0.7007 | 0.5610 | 0.4625 | 0.3895 | 0.3335 | 0.2894 | 0.2538 | 0.2246 | 0.2004 |

# Thermal Overload for Capacitors
ANSI Code 49RMS

## Curves for Initial Heat Rise = 100%

**Is = 1.2 IB**

| **Iph/IBseq** | **1.10** | **1.15** | **1.20** | **1.25** | **1.30** | **1.35** | **1.40** | **1.45** | **1.50** | **1.55** | **1.60** | **1.65** | **1.70** | **1.75** | **1.80** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | | |
| **1.05** | 2.5249 | 1.4422 | 1.0000 | 0.7585 | 0.6064 | 0.5019 | 0.4258 | 0.3679 | 0.3226 | 0.2862 | 0.2563 | 0.2313 | 0.2102 | 0.1922 | 0.1766 |
| **1.10** | | 1.624 | 1.000 | 0.720 | 0.559 | 0.454 | 0.381 | 0.3257 | 0.2835 | 0.2501 | 0.2229 | 0.2004 | 0.1816 | 0.1655 | 0.1518 |
| **1.15** | | | 1.000 | 0.645 | 0.477 | 0.377 | 0.310 | 0.2621 | 0.2260 | 0.1979 | 0.1754 | 0.1570 | 0.1417 | 0.1288 | 0.1177 |

**Is = 1.2 IB**

| **Iph/IBseq** | **1.85** | **1.90** | **1.95** | **2.00** | **2.20** | **2.40** | **2.60** | **2.80** | **3.00** | **3.20** | **3.40** | **3.60** | **3.80** | **4.00** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | |
| **1.05** | 0.1630 | 0.1511 | 0.1405 | 0.1311 | 0.1020 | 0.0821 | 0.0677 | 0.0569 | 0.0486 | 0.0421 | 0.0368 | 0.0325 | 0.0289 | 0.0259 |
| **1.10** | 0.1398 | 0.1293 | 0.1201 | 0.1119 | 0.0867 | 0.0696 | 0.0573 | 0.0481 | 0.0410 | 0.0354 | 0.0310 | 0.0273 | 0.0243 | 0.0217 |
| **1.15** | 0.1082 | 0.0999 | 0.0926 | 0.0861 | 0.0664 | 0.0531 | 0.0436 | 0.0366 | 0.0312 | 0.0269 | 0.0235 | 0.0207 | 0.0184 | 0.0165 |

**Is = 1.3 IB**

| **Iph/IBseq** | **1.10** | **1.15** | **1.20** | **1.25** | **1.30** | **1.35** | **1.40** | **1.45** | **1.50** | **1.55** | **1.60** | **1.65** | **1.70** | **1.75** | **1.80** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | | |
| **1.05** | 4.1639 | 2.3784 | 1.6492 | 1.2509 | 1.0000 | 0.8276 | 0.7021 | 0.6068 | 0.5320 | 0.4719 | 0.4226 | 0.3815 | 0.3467 | 0.3170 | 0.2913 |
| **1.10** | | 2.9020 | 1.7875 | 1.2878 | 1.0000 | 0.8123 | 0.6802 | 0.5823 | 0.5068 | 0.4470 | 0.3984 | 0.3583 | 0.3246 | 0.2959 | 0.2713 |
| **1.15** | | | 2.0959 | 1.3521 | 1.0000 | 0.7901 | 0.6498 | 0.5493 | 0.4737 | 0.4148 | 0.3676 | 0.3291 | 0.2970 | 0.2699 | 0.2468 |
| **1.20** | | | | 1.5014 | 1.0000 | 0.7541 | 0.6039 | 0.5017 | 0.4274 | 0.3708 | 0.3264 | 0.2905 | 0.2610 | 0.2364 | 0.2154 |
| **1.25** | | | | | 1.0000 | 0.6820 | 0.5222 | 0.4227 | 0.3541 | 0.3036 | 0.2648 | 0.2341 | 0.2092 | 0.1886 | 0.1713 |

**Is = 1.3 IB**

| **Iph/IBseq** | **1.85** | **1.90** | **1.95** | **2.00** | **2.20** | **2.40** | **2.60** | **2.80** | **3.00** | **3.20** | **3.40** | **3.60** | **3.80** | **4.00** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | |
| **1.05** | 0.2688 | 0.2491 | 0.2317 | 0.2162 | 0.1682 | 0.1354 | 0.1117 | 0.0939 | 0.0802 | 0.0694 | 0.0607 | 0.0535 | 0.0476 | 0.0426 |
| **1.10** | 0.2499 | 0.2311 | 0.2146 | 0.2000 | 0.1550 | 0.1243 | 0.1023 | 0.0859 | 0.0733 | 0.0633 | 0.0554 | 0.0488 | 0.0434 | 0.0389 |
| **1.15** | 0.2268 | 0.2094 | 0.1941 | 0.1805 | 0.1393 | 0.1114 | 0.0915 | 0.0767 | 0.0653 | 0.0564 | 0.0492 | 0.0434 | 0.0386 | 0.0345 |
| **1.20** | 0.1974 | 0.1819 | 0.1682 | 0.1562 | 0.1199 | 0.0955 | 0.0783 | 0.0655 | 0.0557 | 0.0481 | 0.0419 | 0.0369 | 0.0328 | 0.0293 |
| **1.25** | 0.1565 | 0.1438 | 0.1327 | 0.1230 | 0.0938 | 0.0745 | 0.0609 | 0.0508 | 0.0432 | 0.0372 | 0.0324 | 0.0285 | 0.0253 | 0.0226 |

**Is = 1.4 IB**

| **Iph/IBseq** | **1.10** | **1.15** | **1.20** | **1.25** | **1.30** | **1.35** | **1.40** | **1.45** | **1.50** | **1.55** | **1.60** | **1.65** | **1.70** | **1.75** | **1.80** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | | |
| **1.05** | 5.9304 | 3.3874 | 2.3488 | 1.7816 | 1.4243 | 1.1788 | 1.0000 | 0.8642 | 0.7577 | 0.6721 | 0.6019 | 0.5434 | 0.4938 | 0.4515 | 0.4148 |
| **1.10** | | 4.2662 | 2.6278 | 1.8931 | 1.4701 | 1.1942 | 1.0000 | 0.8560 | 0.7451 | 0.6571 | 0.5857 | 0.5267 | 0.4771 | 0.4350 | 0.3988 |
| **1.15** | | | 3.2252 | 2.0806 | 1.5388 | 1.2158 | 1.0000 | 0.8453 | 0.7289 | 0.6383 | 0.5657 | 0.5064 | 0.4570 | 0.4154 | 0.3797 |
| **1.20** | | | | 2.4862 | 1.6559 | 1.2488 | 1.0000 | 0.8307 | 0.7077 | 0.6141 | 0.5405 | 0.4811 | 0.4323 | 0.3914 | 0.3567 |
| **1.25** | | | | | 1.9151 | 1.3061 | 1.0000 | 0.8095 | 0.6780 | 0.5814 | 0.5072 | 0.4484 | 0.4007 | 0.3612 | 0.3280 |
| **1.30** | | | | | | 1.4393 | 1.0000 | 0.7750 | 0.6330 | 0.5339 | 0.4603 | 0.4035 | 0.3581 | 0.3211 | 0.2903 |
| **1.35** | | | | | | | 1.0000 | 0.7053 | 0.5521 | 0.4544 | 0.3855 | 0.3340 | 0.2940 | 0.2618 | 0.2355 |

**Is = 1.4 IB**

| **Iph/IBseq** | **1.85** | **1.90** | **1.95** | **2.00** | **2.20** | **2.40** | **2.60** | **2.80** | **3.00** | **3.20** | **3.40** | **3.60** | **3.80** | **4.00** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Itrip/IBseq** | | | | | | | | | | | | | | |
| **1.05** | 0.3829 | 0.3548 | 0.3300 | 0.3079 | 0.2396 | 0.1928 | 0.1590 | 0.1337 | 0.1142 | 0.0988 | 0.0864 | 0.0762 | 0.0678 | 0.0607 |
| **1.10** | 0.3673 | 0.3398 | 0.3155 | 0.2940 | 0.2278 | 0.1828 | 0.1505 | 0.1263 | 0.1078 | 0.0931 | 0.0814 | 0.0718 | 0.0638 | 0.0571 |
| **1.15** | 0.3490 | 0.3222 | 0.2986 | 0.2778 | 0.2143 | 0.1714 | 0.1408 | 0.1180 | 0.1005 | 0.0868 | 0.0758 | 0.0668 | 0.0593 | 0.0531 |
| **1.20** | 0.3269 | 0.3011 | 0.2786 | 0.2587 | 0.1985 | 0.1582 | 0.1296 | 0.1085 | 0.0923 | 0.0796 | 0.0694 | 0.0611 | 0.0543 | 0.0486 |
| **1.25** | 0.2997 | 0.2753 | 0.2541 | 0.2355 | 0.1796 | 0.1426 | 0.1165 | 0.0973 | 0.0827 | 0.0712 | 0.0621 | 0.0546 | 0.0485 | 0.0433 |
| **1.30** | 0.2643 | 0.2420 | 0.2228 | 0.2060 | 0.1561 | 0.1235 | 0.1006 | 0.0838 | 0.0711 | 0.0612 | 0.0533 | 0.0468 | 0.0415 | 0.0371 |
| **1.35** | 0.2135 | 0.1948 | 0.1788 | 0.1649 | 0.1240 | 0.0976 | 0.0793 | 0.0659 | 0.0558 | 0.0480 | 0.0417 | 0.0367 | 0.0325 | 0.0290 |

# Thermal Overload for Capacitors
ANSI Code 49RMS

## Curves for Initial Heat Rise = 100%

**Is = 2 IB**

| **Iph/IBseq**<br>**Itrip/IBseq** | **1.10** | **1.15** | **1.20** | **1.25** | **1.30** | **1.35** | **1.40** | **1.45** | **1.50** | **1.55** | **1.60** | **1.65** | **1.70** | **1.75** | **1.80** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.05** | 19.2620 | 11.0020 | 7.6288 | 5.7866 | 4.6259 | 3.8286 | 3.2480 | 2.8069 | 2.4611 | 2.1831 | 1.9550 | 1.7648 | 1.6039 | 1.4663 | 1.3473 |
| **1.10** | | 14.5120 | 8.9388 | 6.4398 | 5.0007 | 4.0622 | 3.4016 | 2.9118 | 2.5344 | 2.2351 | 1.9923 | 1.7915 | 1.6230 | 1.4797 | 1.3565 |
| **1.15** | | | 11.6100 | 7.4893 | 5.5392 | 4.3766 | 3.5996 | 3.0427 | 2.6238 | 2.2975 | 2.0364 | 1.8228 | 1.6451 | 1.4951 | 1.3669 |
| **1.20** | | | | 9.6105 | 6.4010 | 4.8272 | 3.8656 | 3.2112 | 2.7355 | 2.3737 | 2.0892 | 1.8597 | 1.6709 | 1.5129 | 1.3788 |
| **1.25** | | | | | 8.1323 | 5.5465 | 4.2465 | 3.4375 | 2.8792 | 2.4688 | 2.1537 | 1.9041 | 1.7014 | 1.5337 | 1.3927 |
| **1.30** | | | | | | 6.9855 | 4.8534 | 3.7614 | 3.0722 | 2.5911 | 2.2342 | 1.9582 | 1.7380 | 1.5583 | 1.4088 |
| **1.35** | | | | | | | 6.0646 | 4.2771 | 3.3484 | 2.7556 | 2.3380 | 2.0258 | 1.7828 | 1.5879 | 1.4280 |
| **1.40** | | | | | | | | 5.3051 | 3.7883 | 2.9911 | 2.4776 | 2.1131 | 1.8388 | 1.6241 | 1.4511 |
| **1.50** | | | | | | | | | | 4.1166 | 2.9979 | 2.3998 | 2.0090 | 1.7283 | 1.5149 |
| **1.60** | | | | | | | | | | | | 3.2166 | 2.3778 | 1.9239 | 1.6242 |
| **1.70** | | | | | | | | | | | | | | 2.4956 | 1.8670 |

**Is = 2 IB**

| **Iph/IBseq**<br>**Itrip/IBseq** | **1.85** | **1.90** | **1.95** | **2.00** | **2.20** | **2.40** | **2.60** | **2.80** | **3.00** | **3.20** | **3.40** | **3.60** | **3.80** | **4.00** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.05** | 1.2436 | 1.1525 | 1.0718 | 1.0000 | 0.7783 | 0.6262 | 0.5165 | 0.4343 | 0.3709 | 0.3209 | 0.2806 | 0.2476 | 0.2202 | 0.1972 |
| **1.10** | 1.2495 | 1.1559 | 1.0733 | 1.0000 | 0.7750 | 0.6217 | 0.5118 | 0.4297 | 0.3666 | 0.3168 | 0.2768 | 0.2441 | 0.2170 | 0.1943 |
| **1.15** | 1.2562 | 1.1597 | 1.0750 | 1.0000 | 0.7713 | 0.6169 | 0.5066 | 0.4247 | 0.3618 | 0.3124 | 0.2727 | 0.2404 | 0.2136 | 0.1911 |
| **1.20** | 1.2638 | 1.1640 | 1.0768 | 1.0000 | 0.7673 | 0.6115 | 0.5010 | 0.4192 | 0.3567 | 0.3076 | 0.2683 | 0.2363 | 0.2099 | 0.1877 |
| **1.25** | 1.2725 | 1.1690 | 1.0790 | 1.0000 | 0.7628 | 0.6057 | 0.4949 | 0.4133 | 0.3511 | 0.3025 | 0.2636 | 0.2320 | 0.2059 | 0.1841 |
| **1.30** | 1.2826 | 1.1747 | 1.0814 | 1.0000 | 0.7578 | 0.5992 | 0.4882 | 0.4069 | 0.3451 | 0.2969 | 0.2585 | 0.2274 | 0.2017 | 0.1802 |
| **1.35** | 1.2945 | 1.1813 | 1.0842 | 1.0000 | 0.7522 | 0.5920 | 0.4808 | 0.3998 | 0.3386 | 0.2910 | 0.2531 | 0.2224 | 0.1971 | 0.1760 |
| **1.40** | 1.3085 | 1.1891 | 1.0874 | 1.0000 | 0.7459 | 0.5841 | 0.4728 | 0.3921 | 0.3315 | 0.2844 | 0.2471 | 0.2170 | 0.1922 | 0.1715 |
| **1.50** | 1.3463 | 1.2094 | 1.0958 | 1.0000 | 0.7306 | 0.5652 | 0.4539 | 0.3744 | 0.3152 | 0.2697 | 0.2337 | 0.2048 | 0.1811 | 0.1614 |
| **1.60** | 1.4070 | 1.2406 | 1.1082 | 1.0000 | 0.7102 | 0.5410 | 0.4303 | 0.3527 | 0.2955 | 0.2520 | 0.2178 | 0.1904 | 0.1681 | 0.1496 |
| **1.70** | 1.5237 | 1.2953 | 1.1286 | 1.0000 | 0.6816 | 0.5089 | 0.4000 | 0.3253 | 0.2711 | 0.2302 | 0.1983 | 0.1730 | 0.1524 | 0.1355 |

$$\frac{t}{T} = \ln \frac{\left(\frac{Ieq}{IB}\right)^2}{\left(\frac{Ieq}{I_B}\right)^2 - Es}$$

$$\frac{t}{T} = \ln \frac{\left(\frac{Ieq}{I_B}\right)^2 - 1}{\left(\frac{Ieq}{I_B}\right)^2 - Es}$$

# Thermal Overload for Machines
## ANSI Code 49RMS

*Protection of equipment against thermal damage caused by overloads.*

## Description

This function is used to protect equipment (motors, transformers, generators) against overloads, based on measurement of the current drawn.

### Operation Curve

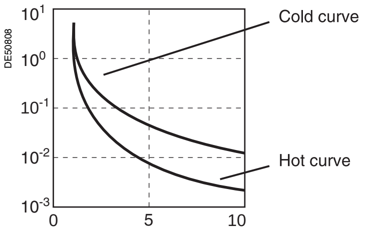
The protection issues a trip command when the heat rise E (calculated by measuring an equivalent current Ieq) is greater than the heat rise set point Es.

The greatest permissible continuous current is

$$I = I_B \sqrt{Es}$$

The protection tripping time is set by the time constant T.

- the calculated heat rise depends on the current drawn and the previous heat rise
- the cold curve defines the protection tripping time based on zero heat rise
- the hot curve defines the protection tripping time based on 100% rated heat rise.



*lN: natural logarithm.*

### Alarm Set Point, Tripping Set Point

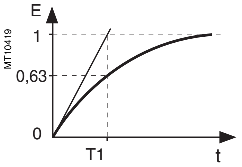
Two set points are available for heat rise:

- Es1: alarm
- Es2: tripping. = $(Imax/I_B)^2$ (if the max operating conditions are unknown use SF x FLA for Imax)

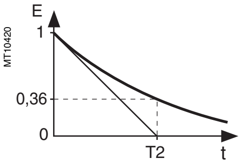
### "Hot State" Set Point

When the function is used to protect a motor, this fixed set point is designed for detection of the hot state used by the number of starts function. The value of the fixed set point is 50%.

### Heat rise and cooling time constants



*Heat rise time constant*



*Cooling time constant*

For self-ventilated rotating machines, cooling is more effective when the machine is running than when it is stopped. Running and stopping of the equipment are calculated based on the value of the current:

- running if I > 0.1 IB
- stopped if I < 0.1 IB

Two time constants may be set:

- T1: heat rise time constant: concerns equipment that is running
- T2: cooling time constant: concerns equipment that is stopped.

### Taking into account harmonics

The current measured by the thermal protection is an RMS 3-phase current which takes into account 13th level harmonics.

### Considering Ambient Temperature

Most machines are designed to operate at a maximum ambient temperature of 104°F (40°C). The thermal overload function takes into account the ambient temperature (Sepam™ equipped with the temperature sensor option[(1)]) to increase the calculated heat rise value when the temperature measured exceeds 104°F (40°C).

Increase factor: $$fa = \frac{Tmax - 40°C}{Tmax - Tambiant}$$

where T max is the equipment maximum temperature (according to insulation class)
T ambient is the measured temperature.

### Table of Insulation Classes

| Class | Y | A | E | B | F | H | 200 | 220 | 250 |
|---|---|---|---|---|---|---|---|---|---|
| Tmax | 90 °C | 105 °C | 120 °C | 130 °C | 155 °C | 180 °C | 200 °C | 220 °C | 250 °C |
| Tmax | 194 °F | 221 °F | 248 °F | 266 °F | 311 °F | 356 °F | 392 °F | 428 °F | 482 °F |

*Reference IEC 60085 (1984).*

### Adaptation of the Protection to Motor Thermal Withstand

Motor thermal protection is often set based on the hot and cold curves supplied by the machine manufacturer.

To fully comply with these experimental curves, additional parameters must be set:

- initial heat rise, Es0, is used to reduce the cold tripping time.

modified cold curve: $$\frac{t}{T} = \ln \frac{\left(\frac{Ieq}{I_B}\right)^2 - Es0}{\left(\frac{Ieq}{I_B}\right)^2 - Es}$$ where ln: natural logarithm

- a second group of parameters (time constants and set points) is used for thermal withstand with locked rotors. This second set of parameters applies when the current is greater than an adjustable set point Is.

### Taking the Negative Sequence Component into Account

For motors with wound rotors, the presence of a negative sequence component increases the heat rise in the motor. The current's negative sequence component is addressed in the protection function by the equation.

$$Ieq = \sqrt{Iph^2 + K \times I2^2}$$ where Iph is the largest phase current
I2 is the negative sequence current component
K is a adjustable coefficient

K may have the following values: 0 - 2.25 - 4.5 - 9
For an asynchronous motor, K is determined as follows:

$$K = 2 \times \frac{Cd}{Cn} \times \frac{1}{g \times \left(\frac{I1}{IB}\right)^2} - 1$$ where Cn, Cd: rated torque and starting torque
IB, I1: base current and starting current
g: rated slip

### Learning the Cooling Time Constant T2

The time constant T2 may be "learned" from the temperatures measured in the equipment by temperature sensors connected to the MET1482 module number 1.
T2 is estimated:

- after a heating/cooling sequence:
  - heating period detected by ES > 70%
  - followed by a shutdown detected by Ieq < 10% of Ib
- when the machine temperature is measured by RTDs connected to MET1482 module number 1:
  - RTD 1, 2, or 3 assigned to motor/generator stator temperature measurement
  - RTD 1, 3, or 5 assigned to transformer temperature measurement.

After each new heating/cooling sequence is detected, a new T2 value is estimated.
Following estimation, T2 can be used in two manners:

- automatically, where each new calculated value updates the T2 constant used
- manually, by entering the value for the T2 parameter.

Measurement accuracy may be improved by using RTD 8 to measure the ambient temperature.

Because the function has two operating modes, a time constant is estimated for each mode.

For generator-transformer unit or motor-transformer unit applications, it is advised to connect the rotating machine RTDs to MET1482 module number 1 to take advantage of T2 learning on the rotating machine rather than on the transformer.

# Thermal Overload for Machines
## ANSI Code 49RMS

**Block Start**
The thermal overload protection can block the closing of the motor control device until the heat rise drops back down below a value that allows restarting. This value addresses the heat rise produced by motor startup.

The block function is grouped together with the **starts per hour** protection function and the indication BLOCK START informs the user.

**Saving the Heat Rise Information**
The current heat rise is saved in the event of an auxiliary power failure.

**Blocking Tripping**
Tripping of the thermal overload protection can be blocked by the logic input "Block thermal overload" when required by the process.

**Use of Two Operating Modes**
The thermal overload protection function may be used to protect equipment with two operating modes, for example:

- transformers with two ventilation modes, with or without forced ventilation (ONAN / ONAF)
- two-speed motors.

The protection function comprises two groups of settings, and each group is suitable for equipment protection in one of the two operating modes.

Switching from one group of thermal settings to the other is done without losing the heat rise information. It is controlled:

- either via a logic input, assigned to the "switching of thermal settings" function
- or when the phase current reaches an adjustable Is set point (to be used for switching of thermal settings of a motor with locked rotor).

The base current of the equipment, used to calculate heat rise, also depends on the operating mode:

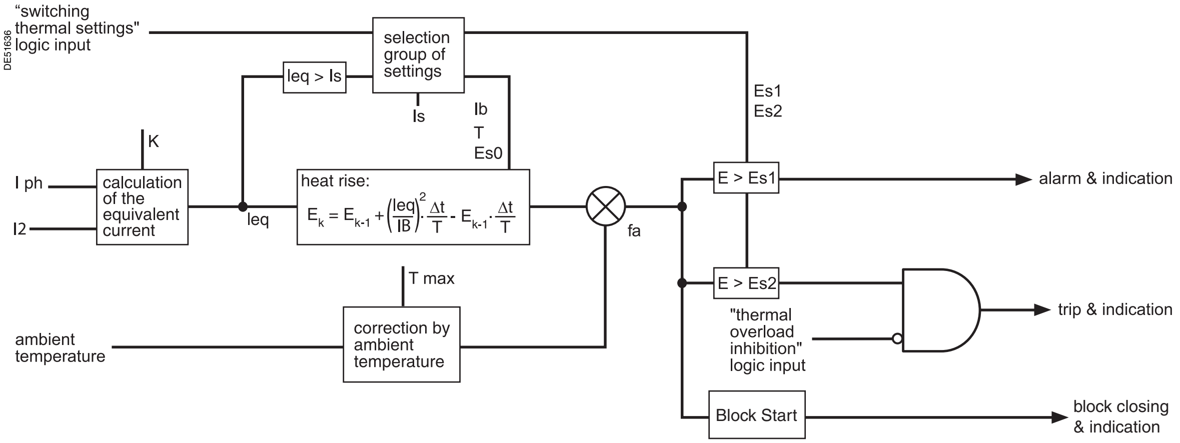
- for logic input switching in mode 2, the base current IB-mode 2, a specific thermal overload protection setting, is used to calculate the heat rise in the equipment
- in all other cases, the base current IB, defined as a general Sepam™ parameter, is used to calculate the heat rise in the equipment.

**User Information**
The following information is available for the user:

- heat rise
- learned cooling time constant T2
- time before restart enabled (in case of blocking starting)
- time before tripping (with constant current).

See the section on measurement and machine operation assistance functions.

### Block Diagram


DE51636
"switching thermal settings" logic input
selection group of settings
Ieq > Is
Is
Ib
T
Es0
Es1
Es2
K
I ph
I2
calculation of the equivalent current
Ieq
heat rise:
$E_k = E_{k-1} + \left(\frac{Ieq}{IB}\right)^2 \cdot \frac{\Delta t}{T} - E_{k-1} \cdot \frac{\Delta t}{T}$
fa
T max
ambient temperature
correction by ambient temperature
E > Es1
alarm & indication
E > Es2
"thermal overload inhibition" logic input
trip & indication
Block Start
block closing & indication

# Thermal Overload for Machines
## Code ANSI 49 RMS

### Characteristics

| **Settings** | |
|---|---|
| **Measurement Origin** | |
| Setting range | Ia, Ib, Ic / I'a, I'b, I'c |
| **Considering the Negative Sequence Component K** | |
| Setting range | 0 - 2.25 - 4.59 |
| **Considering Ambient Temperature** | |
| Setting range | Yes / no |
| **Using the Learned Cooling Time Constant T2** | |
| Setting range | Yes / no |
| **Maximum equipment temperature Tmax (according to insulation class)** | |
| Setting range | 140 °F to 392 °F or 60 °C to 200 °C |
| Resolution | 1°F or 1°C |
| **Thermal Mode 1** | |
| **Alarm Set Point Es1** | |
| Setting range | 0% to 300% |
| Accuracy (1) | ±2% |
| Resolution | 1% |
| **Tripping Set Point Es2** | |
| Setting range | 0% to 300% |
| Accuracy (1) | ±2% |
| Resolution | 1% |
| **Initial Heat Rise Set Point Es0** | |
| Setting range | 0% to 100% |
| Accuracy (1) | ±2% |
| Resolution | 1% |
| **Heat Rise Time Constant T1** | |
| Setting range | 1 min. to 600 min. |
| Resolution | 1 min. |
| **Cooling Time Constant T2** | |
| Setting range | 5 min. to 600 min. |
| Resolution | 1 min. |
| **Thermal Mode 2** | |
| **Using Thermal Mode 2** | |
| Setting range | Yes / no |
| **Alarm Set Point Es1** | |
| Setting range | 0% to 300% |
| Accuracy (1) | ±2% |
| Resolution | 1% |
| **Tripping Set Point Es2** | |
| Setting range | 0% to 300% |
| Accuracy (1) | ±2% |
| Resolution | 1% |
| **Initial Heat Rise Set Point Es0** | |
| Setting range | 0% to 100% |
| Accuracy (1) | ±2% |
| Resolution | 1% |
| **Heat Rise Time Constant T1** | |
| Setting range | 1 min. to 600 min. |
| Resolution | 1 min. |
| **Cooling Time Constant T2** | |
| Setting range | 5 min. to 600 min. |
| Resolution | 1 min. |
| **Switching Set Point for Thermal Mode 2** | |
| Setting range | 25% to 800% of IB |
| Accuracy (1) | ±5% |
| Resolution | 1% |
| **Base Current IB - Mode 2** | |
| Setting range | 0.2 to 2.6 IN or I'N |
| Accuracy (1) | ±5% |
| Resolution | 1 A |
| **Characteristic Times (1)** | |
| Operation time accuracy | ±2% or ±1 s |

*(1) Under reference conditions (IEC 60255-8).*

**Inputs**

| **Designation** | **Syntax** | **Equations** | **Logipam** |
|---|---|---|---|
| Protection reset | P49RMS_1_101 | ■ | ■ |
| Protection blocking | P49RMS_1_113 | ■ | ■ |

**Outputs**

| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
|---|---|---|---|---|
| Delayed output | P49RMS_1_3 | ■ | ■ | ■ |
| Alarm | P49RMS_1_10 | ■ | ■ | ■ |
| Block closing | P49RMS_1_11 | ■ | ■ | ■ |
| Protection blocked | P49RMS_1_16 | ■ | ■ | |
| Hot state | P49RMS_1_18 | ■ | ■ | |
| Block thermal overload | P49RMS_1_32 | ■ | ■ | |

# Thermal Overload for Machines
## ANSI Code 49RMS
## Setting Examples

### Example 1: Motor

The following data are available:

- time constants for on operation T1 and off operation T2:
  - T1 = 25 min.
  - T2 = 70 min.
- maximum steady state current:
  - Imax/IB = 1.05.

**Setting the Tripping Set Point Es2**

Es2 = $(Imax/IB)^2$ = 110%

***Nota :*** *If the motor draws a current of 1.05 IB continuously, the heat rise calculated by the thermal overload protection will reach 110%.*

**Setting Alarm Set Point Es1**

Es1 = 90% (I/IB = 0.95).
Knegative: 4.5 (usual value)

The other thermal overload parameters do not need to be set. They are not considered by default.

### Example 2: Motor

The following data are available:

- motor thermal withstand in the form of hot and cold curves (see solid line curves in Figure 1)
- cooling time constant T2
- maximum steady state current:
- Imax/IB = 1.05.

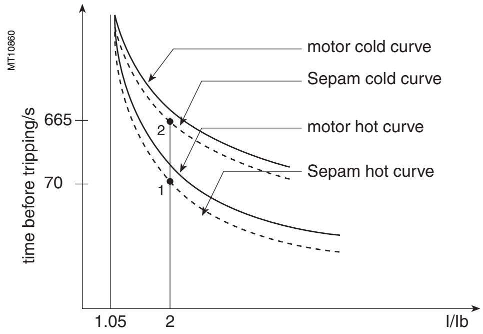
**Setting the Tripping Set Point Es2**

Es2 = $(Imax/IB)^2$ = 110%
Setting of alarm set point Es1:
Es1 = 90% (I/IB = 0.95).

The manufacturer's hot/cold curves (1) may be used to determine the heating time constant T1.

The method consists of placing the Sepam™ hot/cold curves below those of the motor.

**Figure 1. Motor thermal withstand and thermal overload tripping curves.**



For an overload of 2 IB, the value t/T1 = 0.0339 (2).
In order for Sepam™ to trip at point 1 (t = 70 s), T1 is equal to 2065 sec ≈ 34 min.

With a setting of T1 = 34 min., the tripping time is obtained based on a cold state (point 2). Here, it is equal to t/T1 = 0.3216 ⇒ t = 665 sec, that is,. ≈ 11 minutes, which is compatible with the motor thermal withstand when it is cold.

The negative sequence factor K is calculated using the equation defined on page 109.

The parameters of the second thermal overload relay do not need to be set. They are not considered by default.

### Example 3: Motor

The following data are available:

- motor thermal withstand in the form of hot and cold curves (see solid line curves in Figure 2)
- cooling time constant T2
- maximum steady state current: Imax/Ib = 1.1.

The thermal overload parameters are determined as in the previous example.

**Setting the Tripping Set Point Es2**

Es2 = $(Imax/IB)^2$ = 120%

**Setting the Alarm Set Point Es1**

Es1 = 90% (I/IB = 0.95).
The time constant T1 is calculated so that the thermal overload protection trips after 100 seconds (point 1).
With t/T1 = 0.069 (I/IB = 2 and Es2 = 120%):
⇒ T1 = 100 sec / 0.069 = 1449 sec ≈ 24 min.

The tripping time starting from the cold state is equal to:
t/T1 = 0.3567 ⇒ t = 24 min. x 0.3567 = 513 sec (point 2').

This tripping time is too long since the limit for this overload current is 400 sec (point 2).

If the time constant T1 is lowered, the thermal overload protection will trip earlier, below point 2.

The risk that motor starting when hot will not be possible also exists in this case (see Figure 2 in which a lower Sepam™ hot curve would intersect the starting curve with $V_{LL} = 0.9\ V_{LL}$).

The **Es0 parameter** is a setting that is used to solve these differences by lowering the Sepam™ cold curve without moving the hot curve. In this example, the thermal overload protection should trip after 400 sec starting from the cold state.

The following equation is used to obtain the Es0 value:

$$\mathbf{Es0} = \left[\frac{I_{processed}}{I_B}\right]^2 - e^{\frac{t_{necessary}}{T_1}} \times \left[\left[\frac{I_{processed}}{I_B}\right]^2 - \mathbf{Es2}\right]$$

where:
$t_{necessary}$: tripping time necessary starting from a cold state.
$I_{processed}$: equipment current.

---

***(1)*** *When the machine manufacturer provides both a time constant T1 and the machine hot/cold curves, the use of the curves is recommended since they are more accurate.*
***(2)*** *It is possible to use the charts containing the numerical values of the Sepam™ hot curve or the equation of the curve which is given on page 108.*

# Thermal Overload for Machines
## ANSI Code 49RMS
## Setting Examples

In numerical values, the following is obtained:

$$\mathbf{Es0} = 4 - e^{\frac{400\ s}{24 \times 60\ s}} \times \left[4 - (1.2)\right] = 0.3035 \approx (31\,\%)$$

By setting Es0 = 31%, point 2’ is moved downward to obtain a shorter tripping time that is compatible with the motor thermal withstand when cold (see Figure 3).

***Nota :*** *A setting Es0 = 100% means that the hot and cold curves are the same.*

**Figure 2. Hot/cold curves incompatible with the motor thermal withstand.**

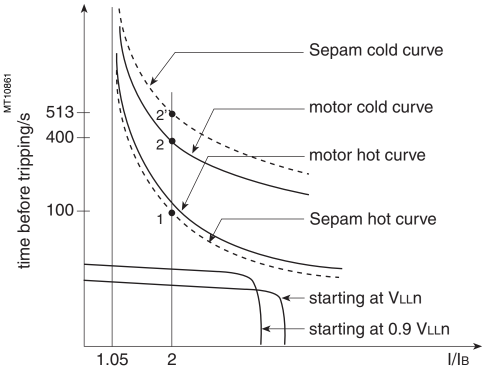
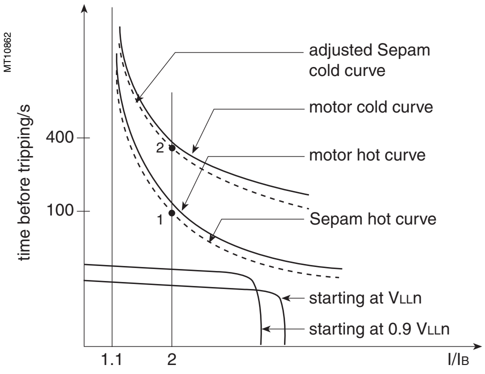


**Figure 3. Hot/cold curves compatible with the motor thermal withstand via the setting of an initial heat rise Es0.**



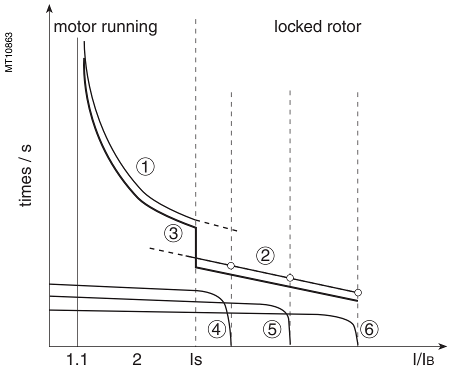
**Using the Additional Setting Group**

When a motor rotor is locked or turning very slowly, its thermal behavior differs from one with a rated load. In such conditions, the motor is damaged by overheating of the rotor or stator. For high power motors, rotor overheating is usually a limiting factor.

The thermal overload parameters selected to operate with a low overload are no longer valid. In order to protect the motor in this case, "excessive starting time" protection may be used.

However, motor manufacturers provide the thermal withstand curves when the rotor is locked, for different voltages at the time of starting.

**Figure 4. Locked Rotor Thermal Withstand.**



① : thermal withstand, motor running
② : thermal withstand, motor stopped
③ : Sepam™ tripping curve
④ : starting at 65% $V_{LL}$
⑤ : starting at 80% $V_{LL}$
⑥ : starting at 100% $V_{LL}$

In order to consider these curves, a second thermal overload relay can be used. The time constant in this case is theoretically shorter. It should, however, be determined in the same way as that of the first relay.

The thermal overload protection switches between the first and second relay if the equivalent current Ieq exceeds the Is value (set point current).

## Example 4. Transformer with Two Ventilation Modes

The following data are available:
The rated current of a transformer with two ventilation modes is:

- IB = 200 A without forced ventilation (ONAN mode), the main operating mode of the transformer
- IB = 240 A with forced ventilation (ONAF mode), a temporary operating mode, to have 20% more power available

Setting the base current for ventilation operating mode 1: IB = 200 A (to be set in the Sepam™ general parameters).

Setting the base current for ventilation operating mode 2: IB2 = 240 A (to be set among the specific thermal overload protection settings).

Switching thermal settings by the logic input, to be assigned to "switching thermal settings" function and to be connected to the transformer ventilation control unit.

Settings related to each ventilation operating mode (Es set points, time constants, etc.) are determined according to transformer characteristics provided by the manufacturer.

## Cold Curves for Es0 = 0%

| I/IB<br>Es (%) | 1.00 | 1.05 | 1.10 | 1.15 | 1.20 | 1.25 | 1.30 | 1.35 | 1.40 | 1.45 | 1.50 | 1.55 | 1.60 | 1.65 | 1.70 | 1.75 | 1.80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **50** | 0.6931 | 0.6042 | 0.5331 | 0.4749 | 0.4265 | 0.3857 | 0.3508 | 0.3207 | 0.2945 | 0.2716 | 0.2513 | 0.2333 | 0.2173 | 0.2029 | 0.1900 | 0.1782 | 0.1676 |
| **55** | 0.7985 | 0.6909 | 0.6061 | 0.5376 | 0.4812 | 0.4339 | 0.3937 | 0.3592 | 0.3294 | 0.3033 | 0.2803 | 0.2600 | 0.2419 | 0.2257 | 0.2111 | 0.1980 | 0.1860 |
| **60** | 0.9163 | 0.7857 | 0.6849 | 0.6046 | 0.5390 | 0.4845 | 0.4386 | 0.3993 | 0.3655 | 0.3360 | 0.3102 | 0.2873 | 0.2671 | 0.2490 | 0.2327 | 0.2181 | 0.2048 |
| **65** | 1.0498 | 0.8905 | 0.7704 | 0.6763 | 0.6004 | 0.5379 | 0.4855 | 0.4411 | 0.4029 | 0.3698 | 0.3409 | 0.3155 | 0.2929 | 0.2728 | 0.2548 | 0.2386 | 0.2239 |
| **70** | 1.2040 | 1.0076 | 0.8640 | 0.7535 | 0.6657 | 0.5942 | 0.5348 | 0.4847 | 0.4418 | 0.4049 | 0.3727 | 0.3444 | 0.3194 | 0.2972 | 0.2774 | 0.2595 | 0.2434 |
| **75** | 1.3863 | 1.1403 | 0.9671 | 0.8373 | 0.7357 | 0.6539 | 0.5866 | 0.5302 | 0.4823 | 0.4412 | 0.4055 | 0.3742 | 0.3467 | 0.3222 | 0.3005 | 0.2809 | 0.2633 |
| **80** | 1.6094 | 1.2933 | 1.0822 | 0.9287 | 0.8109 | 0.7174 | 0.6413 | 0.5780 | 0.5245 | 0.4788 | 0.4394 | 0.4049 | 0.3747 | 0.3479 | 0.3241 | 0.3028 | 0.2836 |
| **85** | 1.8971 | 1.4739 | 1.2123 | 1.0292 | 0.8923 | 0.7853 | 0.6991 | 0.6281 | 0.5686 | 0.5180 | 0.4745 | 0.4366 | 0.4035 | 0.3743 | 0.3483 | 0.3251 | 0.3043 |
| **90** | 2.3026 | 1.6946 | 1.3618 | 1.1411 | 0.9808 | 0.8580 | 0.7605 | 0.6809 | 0.6147 | 0.5587 | 0.5108 | 0.4694 | 0.4332 | 0.4013 | 0.3731 | 0.3480 | 0.3254 |
| **95** |  | 1.9782 | 1.5377 | 1.2670 | 1.0780 | 0.9365 | 0.8258 | 0.7366 | 0.6630 | 0.6012 | 0.5486 | 0.5032 | 0.4638 | 0.4292 | 0.3986 | 0.3714 | 0.3470 |
| **100** |  | 2.3755 | 1.7513 | 1.4112 | 1.1856 | 1.0217 | 0.8958 | 0.7956 | 0.7138 | 0.6455 | 0.5878 | 0.5383 | 0.4953 | 0.4578 | 0.4247 | 0.3953 | 0.3691 |
| **105** |  | 3.0445 | 2.0232 | 1.5796 | 1.3063 | 1.1147 | 0.9710 | 0.8583 | 0.7673 | 0.6920 | 0.6286 | 0.5746 | 0.5279 | 0.4872 | 0.4515 | 0.4199 | 0.3917 |
| **110** |  |  | 2.3979 | 1.7824 | 1.4435 | 1.2174 | 1.0524 | 0.9252 | 0.8238 | 0.7406 | 0.6712 | 0.6122 | 0.5616 | 0.5176 | 0.4790 | 0.4450 | 0.4148 |
| **115** |  |  | 3.0040 | 2.0369 | 1.6025 | 1.3318 | 1.1409 | 0.9970 | 0.8837 | 0.7918 | 0.7156 | 0.6514 | 0.5964 | 0.5489 | 0.5074 | 0.4708 | 0.4384 |
| **120** |  |  |  | 2.3792 | 1.7918 | 1.4610 | 1.2381 | 1.0742 | 0.9474 | 0.8457 | 0.7621 | 0.6921 | 0.6325 | 0.5812 | 0.5365 | 0.4973 | 0.4626 |
| **125** |  |  |  | 2.9037 | 2.0254 | 1.6094 | 1.3457 | 1.1580 | 1.0154 | 0.9027 | 0.8109 | 0.7346 | 0.6700 | 0.6146 | 0.5666 | 0.5245 | 0.4874 |
| **130** |  |  |  |  | 2.3308 | 1.7838 | 1.4663 | 1.2493 | 1.0885 | 0.9632 | 0.8622 | 0.7789 | 0.7089 | 0.6491 | 0.5975 | 0.5525 | 0.5129 |
| **135** |  |  |  |  | 2.7726 | 1.9951 | 1.6035 | 1.3499 | 1.1672 | 1.0275 | 0.9163 | 0.8253 | 0.7494 | 0.6849 | 0.6295 | 0.5813 | 0.5390 |
| **140** |  |  |  |  |  | 2.2634 | 1.7626 | 1.4618 | 1.2528 | 1.0962 | 0.9734 | 0.8740 | 0.7916 | 0.7220 | 0.6625 | 0.6109 | 0.5658 |
| **145** |  |  |  |  |  | 2.6311 | 1.9518 | 1.5877 | 1.3463 | 1.1701 | 1.0341 | 0.9252 | 0.8356 | 0.7606 | 0.6966 | 0.6414 | 0.5934 |
| **150** |  |  |  |  |  | 3.2189 | 2.1855 | 1.7319 | 1.4495 | 1.2498 | 1.0986 | 0.9791 | 0.8817 | 0.8007 | 0.7320 | 0.6729 | 0.6217 |
| **155** |  |  |  |  |  |  | 2.4908 | 1.9003 | 1.5645 | 1.3364 | 1.1676 | 1.0361 | 0.9301 | 0.8424 | 0.7686 | 0.7055 | 0.6508 |
| **160** |  |  |  |  |  |  | 2.9327 | 2.1030 | 1.6946 | 1.4313 | 1.2417 | 1.0965 | 0.9808 | 0.8860 | 0.8066 | 0.7391 | 0.6809 |
| **165** |  |  |  |  |  |  |  | 2.3576 | 1.8441 | 1.5361 | 1.3218 | 1.1609 | 1.0343 | 0.9316 | 0.8461 | 0.7739 | 0.7118 |
| **170** |  |  |  |  |  |  |  | 2.6999 | 2.0200 | 1.6532 | 1.4088 | 1.2296 | 1.0908 | 0.9793 | 0.8873 | 0.8099 | 0.7438 |
| **175** |  |  |  |  |  |  |  | 3.2244 | 2.2336 | 1.7858 | 1.5041 | 1.3035 | 1.1507 | 1.0294 | 0.9302 | 0.8473 | 0.7768 |
| **180** |  |  |  |  |  |  |  |  | 2.5055 | 1.9388 | 1.6094 | 1.3832 | 1.2144 | 1.0822 | 0.9751 | 0.8861 | 0.8109 |
| **185** |  |  |  |  |  |  |  |  | 2.8802 | 2.1195 | 1.7272 | 1.4698 | 1.2825 | 1.1379 | 1.0220 | 0.9265 | 0.8463 |
| **190** |  |  |  |  |  |  |  |  | 3.4864 | 2.3401 | 1.8608 | 1.5647 | 1.3555 | 1.1970 | 1.0713 | 0.9687 | 0.8829 |
| **195** |  |  |  |  |  |  |  |  |  | 2.6237 | 2.0149 | 1.6695 | 1.4343 | 1.2597 | 1.1231 | 1.0126 | 0.9209 |
| **200** |  |  |  |  |  |  |  |  |  | 3.0210 | 2.1972 | 1.7866 | 1.5198 | 1.3266 | 1.1778 | 1.0586 | 0.9605 |

### Cold Curves for Es0 = 0%

| **I/IB** | **1.85** | **1.90** | **1.95** | **2.00** | **2.20** | **2.40** | **2.60** | **2.80** | **3.00** | **3.20** | **3.40** | **3.60** | **3.80** | **4.00** | **4.20** | **4.40** | **4.60** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Es (%)** | | | | | | | | | | | | | | | | | |
| **50** | 0.1579 | 0.1491 | 0.1410 | 0.1335 | 0.1090 | 0.0908 | 0.0768 | 0.0659 | 0.0572 | 0.0501 | 0.0442 | 0.0393 | 0.0352 | 0.0317 | 0.0288 | 0.0262 | 0.0239 |
| **55** | 0.1752 | 0.1653 | 0.1562 | 0.1479 | 0.1206 | 0.1004 | 0.0849 | 0.0727 | 0.0631 | 0.0552 | 0.0487 | 0.0434 | 0.0388 | 0.0350 | 0.0317 | 0.0288 | 0.0263 |
| **60** | 0.1927 | 0.1818 | 0.1717 | 0.1625 | 0.1324 | 0.1100 | 0.0929 | 0.0796 | 0.069 | 0.0604 | 0.0533 | 0.0474 | 0.0424 | 0.0382 | 0.0346 | 0.0315 | 0.0288 |
| **65** | 0.2106 | 0.1985 | 0.1875 | 0.1773 | 0.1442 | 0.1197 | 0.1011 | 0.0865 | 0.075 | 0.0656 | 0.0579 | 0.0515 | 0.0461 | 0.0415 | 0.0375 | 0.0342 | 0.0312 |
| **70** | 0.2288 | 0.2156 | 0.2035 | 0.1924 | 0.1562 | 0.1296 | 0.1093 | 0.0935 | 0.081 | 0.0708 | 0.0625 | 0.0555 | 0.0497 | 0.0447 | 0.0405 | 0.0368 | 0.0336 |
| **75** | 0.2474 | 0.2329 | 0.2197 | 0.2076 | 0.1684 | 0.1395 | 0.1176 | 0.1006 | 0.087 | 0.0761 | 0.0671 | 0.0596 | 0.0533 | 0.0480 | 0.0434 | 0.0395 | 0.0361 |
| **80** | 0.2662 | 0.2505 | 0.2362 | 0.2231 | 0.1807 | 0.1495 | 0.1260 | 0.1076 | 0.0931 | 0.0813 | 0.0717 | 0.0637 | 0.0570 | 0.0513 | 0.0464 | 0.0422 | 0.0385 |
| **85** | 0.2855 | 0.2685 | 0.2530 | 0.2389 | 0.1931 | 0.1597 | 0.1344 | 0.1148 | 0.0992 | 0.0867 | 0.0764 | 0.0678 | 0.0607 | 0.0546 | 0.0494 | 0.0449 | 0.0410 |
| **90** | 0.3051 | 0.2868 | 0.2701 | 0.2549 | 0.2057 | 0.1699 | 0.1429 | 0.1219 | 0.1054 | 0.092 | 0.0811 | 0.0720 | 0.0644 | 0.0579 | 0.0524 | 0.0476 | 0.0435 |
| **95** | 0.3251 | 0.3054 | 0.2875 | 0.2712 | 0.2185 | 0.1802 | 0.1514 | 0.1292 | 0.1116 | 0.0974 | 0.0858 | 0.0761 | 0.0681 | 0.0612 | 0.0554 | 0.0503 | 0.0459 |
| **100** | 0.3456 | 0.3244 | 0.3051 | 0.2877 | 0.2314 | 0.1907 | 0.1601 | 0.1365 | 0.1178 | 0.1028 | 0.0905 | 0.0803 | 0.0718 | 0.0645 | 0.0584 | 0.0530 | 0.0484 |
| **105** | 0.3664 | 0.3437 | 0.3231 | 0.3045 | 0.2445 | 0.2012 | 0.1688 | 0.1438 | 0.1241 | 0.1082 | 0.0952 | 0.0845 | 0.0755 | 0.0679 | 0.0614 | 0.0558 | 0.0509 |
| **110** | 0.3877 | 0.3634 | 0.3415 | 0.3216 | 0.2578 | 0.2119 | 0.1776 | 0.1512 | 0.1304 | 0.1136 | 0.1000 | 0.0887 | 0.0792 | 0.0712 | 0.0644 | 0.0585 | 0.0534 |
| **115** | 0.4095 | 0.3835 | 0.3602 | 0.3390 | 0.2713 | 0.2227 | 0.1865 | 0.1586 | 0.1367 | 0.1191 | 0.1048 | 0.0929 | 0.0830 | 0.0746 | 0.0674 | 0.0612 | 0.0559 |
| **120** | 0.4317 | 0.4041 | 0.3792 | 0.3567 | 0.2849 | 0.2336 | 0.1954 | 0.1661 | 0.1431 | 0.1246 | 0.1096 | 0.0972 | 0.0868 | 0.0780 | 0.0705 | 0.0640 | 0.0584 |
| **125** | 0.4545 | 0.4250 | 0.3986 | 0.3747 | 0.2988 | 0.2446 | 0.2045 | 0.1737 | 0.1495 | 0.1302 | 0.1144 | 0.1014 | 0.0905 | 0.0813 | 0.0735 | 0.0667 | 0.0609 |
| **130** | 0.4778 | 0.4465 | 0.4184 | 0.3930 | 0.3128 | 0.2558 | 0.2136 | 0.1813 | 0.156 | 0.1358 | 0.1193 | 0.1057 | 0.0943 | 0.0847 | 0.0766 | 0.0695 | 0.0634 |
| **135** | 0.5016 | 0.4683 | 0.4386 | 0.4117 | 0.3270 | 0.2671 | 0.2228 | 0.1890 | 0.1625 | 0.1414 | 0.1242 | 0.1100 | 0.0982 | 0.0881 | 0.0796 | 0.0723 | 0.0659 |
| **140** | 0.5260 | 0.4907 | 0.4591 | 0.4308 | 0.3414 | 0.2785 | 0.2321 | 0.1967 | 0.1691 | 0.147 | 0.1291 | 0.1143 | 0.1020 | 0.0916 | 0.0827 | 0.0751 | 0.0685 |
| **145** | 0.5511 | 0.5136 | 0.4802 | 0.4502 | 0.3561 | 0.2900 | 0.2414 | 0.2045 | 0.1757 | 0.1527 | 0.1340 | 0.1187 | 0.1058 | 0.0950 | 0.0858 | 0.0778 | 0.0710 |
| **150** | 0.5767 | 0.5370 | 0.5017 | 0.4700 | 0.3709 | 0.3017 | 0.2509 | 0.2124 | 0.1823 | 0.1584 | 0.1390 | 0.1230 | 0.1097 | 0.0984 | 0.0889 | 0.0806 | 0.0735 |
| **155** | 0.6031 | 0.5610 | 0.5236 | 0.4902 | 0.3860 | 0.3135 | 0.2604 | 0.2203 | 0.189 | 0.1641 | 0.1440 | 0.1274 | 0.1136 | 0.1019 | 0.0920 | 0.0834 | 0.0761 |
| **160** | 0.6302 | 0.5856 | 0.5461 | 0.5108 | 0.4013 | 0.3254 | 0.2701 | 0.2283 | 0.1957 | 0.1699 | 0.1490 | 0.1318 | 0.1174 | 0.1054 | 0.0951 | 0.0863 | 0.0786 |
| **165** | 0.6580 | 0.6108 | 0.5690 | 0.5319 | 0.4169 | 0.3375 | 0.2798 | 0.2363 | 0.2025 | 0.1757 | 0.1540 | 0.1362 | 0.1213 | 0.1088 | 0.0982 | 0.0891 | 0.0812 |
| **170** | 0.6866 | 0.6366 | 0.5925 | 0.5534 | 0.4327 | 0.3498 | 0.2897 | 0.2444 | 0.2094 | 0.1815 | 0.1591 | 0.1406 | 0.1253 | 0.1123 | 0.1013 | 0.0919 | 0.0838 |
| **175** | 0.7161 | 0.6631 | 0.6166 | 0.5754 | 0.4487 | 0.3621 | 0.2996 | 0.2526 | 0.2162 | 0.1874 | 0.1641 | 0.1451 | 0.1292 | 0.1158 | 0.1045 | 0.0947 | 0.0863 |
| **180** | 0.7464 | 0.6904 | 0.6413 | 0.5978 | 0.4651 | 0.3747 | 0.3096 | 0.2608 | 0.2231 | 0.1933 | 0.1693 | 0.1495 | 0.1331 | 0.1193 | 0.1076 | 0.0976 | 0.0889 |
| **185** | 0.7777 | 0.7184 | 0.6665 | 0.6208 | 0.4816 | 0.3874 | 0.3197 | 0.2691 | 0.2301 | 0.1993 | 0.1744 | 0.1540 | 0.1371 | 0.1229 | 0.1108 | 0.1004 | 0.0915 |
| **190** | 0.8100 | 0.7472 | 0.6925 | 0.6444 | 0.4985 | 0.4003 | 0.3300 | 0.2775 | 0.2371 | 0.2052 | 0.1796 | 0.1585 | 0.1411 | 0.1264 | 0.1140 | 0.1033 | 0.0941 |
| **195** | 0.8434 | 0.7769 | 0.7191 | 0.6685 | 0.5157 | 0.4133 | 0.3403 | 0.2860 | 0.2442 | 0.2113 | 0.1847 | 0.1631 | 0.1451 | 0.1300 | 0.1171 | 0.1062 | 0.0967 |
| **200** | 0.8780 | 0.8075 | 0.7465 | 0.6931 | 0.5331 | 0.4265 | 0.3508 | 0.2945 | 0.2513 | 0.2173 | 0.1900 | 0.1676 | 0.1491 | 0.1335 | 0.1203 | 0.1090 | 0.0993 |

# Thermal Overload for Machines

## ANSI Code 49RMS

## Trip Curves

### Cold Curves for Es0 = 0%

| **I/IB<br>Es (%)** | **4.80** | **5.00** | **5.50** | **6.00** | **6.50** | **7.00** | **7.50** | **8.00** | **8.50** | **9.00** | **9.50** | **10.00** | **12.50** | **15.00** | **17.50** | **20.00** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **50** | 0.0219 | 0.0202 | 0.0167 | 0.0140 | 0.0119 | 0.0103 | 0.0089 | 0.0078 | 0.0069 | 0.0062 | 0.0056 | 0.0050 | 0.0032 | 0.0022 | 0.0016 | 0.0013 |
| **55** | 0.0242 | 0.0222 | 0.0183 | 0.0154 | 0.0131 | 0.0113 | 0.0098 | 0.0086 | 0.0076 | 0.0068 | 0.0061 | 0.0055 | 0.0035 | 0.0024 | 0.0018 | 0.0014 |
| **60** | 0.0264 | 0.0243 | 0.0200 | 0.0168 | 0.0143 | 0.0123 | 0.0107 | 0.0094 | 0.0083 | 0.0074 | 0.0067 | 0.0060 | 0.0038 | 0.0027 | 0.0020 | 0.0015 |
| **65** | 0.0286 | 0.0263 | 0.0217 | 0.0182 | 0.0155 | 0.0134 | 0.0116 | 0.0102 | 0.0090 | 0.0081 | 0.0072 | 0.0065 | 0.0042 | 0.0029 | 0.0021 | 0.0016 |
| **70** | 0.0309 | 0.0284 | 0.0234 | 0.0196 | 0.0167 | 0.0144 | 0.0125 | 0.0110 | 0.0097 | 0.0087 | 0.0078 | 0.0070 | 0.0045 | 0.0031 | 0.0023 | 0.0018 |
| **75** | 0.0331 | 0.0305 | 0.0251 | 0.0211 | 0.0179 | 0.0154 | 0.0134 | 0.0118 | 0.0104 | 0.0093 | 0.0083 | 0.0075 | 0.0048 | 0.0033 | 0.0025 | 0.0019 |
| **80** | 0.0353 | 0.0325 | 0.0268 | 0.0225 | 0.0191 | 0.0165 | 0.0143 | 0.0126 | 0.0111 | 0.0099 | 0.0089 | 0.0080 | 0.0051 | 0.0036 | 0.0026 | 0.0020 |
| **85** | 0.0376 | 0.0346 | 0.0285 | 0.0239 | 0.0203 | 0.0175 | 0.0152 | 0.0134 | 0.0118 | 0.0105 | 0.0095 | 0.0085 | 0.0055 | 0.0038 | 0.0028 | 0.0021 |
| **90** | 0.0398 | 0.0367 | 0.0302 | 0.0253 | 0.0215 | 0.0185 | 0.0161 | 0.0142 | 0.0125 | 0.0112 | 0.0100 | 0.0090 | 0.0058 | 0.0040 | 0.0029 | 0.0023 |
| **95** | 0.0421 | 0.0387 | 0.0319 | 0.0267 | 0.0227 | 0.0196 | 0.0170 | 0.0150 | 0.0132 | 0.0118 | 0.0106 | 0.0095 | 0.0061 | 0.0042 | 0.0031 | 0.0024 |
| **100** | 0.0444 | 0.0408 | 0.0336 | 0.0282 | 0.0240 | 0.0206 | 0.0179 | 0.0157 | 0.0139 | 0.0124 | 0.0111 | 0.0101 | 0.0064 | 0.0045 | 0.0033 | 0.0025 |
| **105** | 0.0466 | 0.0429 | 0.0353 | 0.0296 | 0.0252 | 0.0217 | 0.0188 | 0.0165 | 0.0146 | 0.0130 | 0.0117 | 0.0106 | 0.0067 | 0.0047 | 0.0034 | 0.0026 |
| **110** | 0.0489 | 0.0450 | 0.0370 | 0.0310 | 0.0264 | 0.0227 | 0.0197 | 0.0173 | 0.0153 | 0.0137 | 0.0123 | 0.0111 | 0.0071 | 0.0049 | 0.0036 | 0.0028 |
| **115** | 0.0512 | 0.0471 | 0.0388 | 0.0325 | 0.0276 | 0.0237 | 0.0207 | 0.0181 | 0.0160 | 0.0143 | 0.0128 | 0.0116 | 0.0074 | 0.0051 | 0.0038 | 0.0029 |
| **120** | 0.0535 | 0.0492 | 0.0405 | 0.0339 | 0.0288 | 0.0248 | 0.0216 | 0.0189 | 0.0167 | 0.0149 | 0.0134 | 0.0121 | 0.0077 | 0.0053 | 0.0039 | 0.0030 |
| **125** | 0.0558 | 0.0513 | 0.0422 | 0.0353 | 0.0300 | 0.0258 | 0.0225 | 0.0197 | 0.0175 | 0.0156 | 0.0139 | 0.0126 | 0.0080 | 0.0056 | 0.0041 | 0.0031 |
| **130** | 0.0581 | 0.0534 | 0.0439 | 0.0368 | 0.0313 | 0.0269 | 0.0234 | 0.0205 | 0.0182 | 0.0162 | 0.0145 | 0.0131 | 0.0084 | 0.0058 | 0.0043 | 0.0033 |
| **135** | 0.0604 | 0.0555 | 0.0457 | 0.0382 | 0.0325 | 0.0279 | 0.0243 | 0.0213 | 0.0189 | 0.0168 | 0.0151 | 0.0136 | 0.0087 | 0.0060 | 0.0044 | 0.0034 |
| **140** | 0.0627 | 0.0576 | 0.0474 | 0.0397 | 0.0337 | 0.0290 | 0.0252 | 0.0221 | 0.0196 | 0.0174 | 0.0156 | 0.0141 | 0.0090 | 0.0062 | 0.0046 | 0.0035 |
| **145** | 0.0650 | 0.0598 | 0.0491 | 0.0411 | 0.0349 | 0.0300 | 0.0261 | 0.0229 | 0.0203 | 0.0181 | 0.0162 | 0.0146 | 0.0093 | 0.0065 | 0.0047 | 0.0036 |
| **150** | 0.0673 | 0.0619 | 0.0509 | 0.0426 | 0.0361 | 0.0311 | 0.0270 | 0.0237 | 0.0210 | 0.0187 | 0.0168 | 0.0151 | 0.0096 | 0.0067 | 0.0049 | 0.0038 |
| **155** | 0.0696 | 0.0640 | 0.0526 | 0.0440 | 0.0374 | 0.0321 | 0.0279 | 0.0245 | 0.0217 | 0.0193 | 0.0173 | 0.0156 | 0.0100 | 0.0069 | 0.0051 | 0.0039 |
| **160** | 0.0720 | 0.0661 | 0.0543 | 0.0455 | 0.0386 | 0.0332 | 0.0289 | 0.0253 | 0.0224 | 0.0200 | 0.0179 | 0.0161 | 0.0103 | 0.0071 | 0.0052 | 0.0040 |
| **165** | 0.0743 | 0.0683 | 0.0561 | 0.0469 | 0.0398 | 0.0343 | 0.0298 | 0.0261 | 0.0231 | 0.0206 | 0.0185 | 0.0166 | 0.0106 | 0.0074 | 0.0054 | 0.0041 |
| **170** | 0.0766 | 0.0704 | 0.0578 | 0.0484 | 0.0411 | 0.0353 | 0.0307 | 0.0269 | 0.0238 | 0.0212 | 0.0190 | 0.0171 | 0.0109 | 0.0076 | 0.0056 | 0.0043 |
| **175** | 0.0790 | 0.0726 | 0.0596 | 0.0498 | 0.0423 | 0.0364 | 0.0316 | 0.0277 | 0.0245 | 0.0218 | 0.0196 | 0.0177 | 0.0113 | 0.0078 | 0.0057 | 0.0044 |
| **180** | 0.0813 | 0.0747 | 0.0613 | 0.0513 | 0.0435 | 0.0374 | 0.0325 | 0.0285 | 0.0252 | 0.0225 | 0.0201 | 0.0182 | 0.0116 | 0.0080 | 0.0059 | 0.0045 |
| **185** | 0.0837 | 0.0769 | 0.0631 | 0.0528 | 0.0448 | 0.0385 | 0.0334 | 0.0293 | 0.0259 | 0.0231 | 0.0207 | 0.0187 | 0.0119 | 0.0083 | 0.0061 | 0.0046 |
| **190** | 0.0861 | 0.0790 | 0.0649 | 0.0542 | 0.0460 | 0.0395 | 0.0344 | 0.0301 | 0.0266 | 0.0237 | 0.0213 | 0.0192 | 0.0122 | 0.0085 | 0.0062 | 0.0048 |
| **195** | 0.0884 | 0.0812 | 0.0666 | 0.0557 | 0.0473 | 0.0406 | 0.0353 | 0.0309 | 0.0274 | 0.0244 | 0.0218 | 0.0197 | 0.0126 | 0.0087 | 0.0064 | 0.0049 |
| **200** | 0.0908 | 0.0834 | 0.0684 | 0.0572 | 0.0485 | 0.0417 | 0.0362 | 0.0317 | 0.0281 | 0.0250 | 0.0224 | 0.0202 | 0.0129 | 0.0089 | 0.0066 | 0.0050 |

# Thermal Overload for Machines
## ANSI Code 49RMS
### Trip Curves

### Hot Curves

| I/IB<br>Es (%) | 1.00 | 1.05 | 1.10 | 1.15 | 1.20 | 1.25 | 1.30 | 1.35 | 1.40 | 1.45 | 1.50 | 1.55 | 1.60 | 1.65 | 1.70 | 1.75 | 1.80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **105** | | 0.6690 | 0.2719 | 0.1685 | 0.1206 | 0.0931 | 0.0752 | 0.0627 | 0.0535 | 0.0464 | 0.0408 | 0.0363 | 0.0326 | 0.0295 | 0.0268 | 0.0245 | 0.0226 |
| **110** | | 3.7136 | 0.6466 | 0.3712 | 0.2578 | 0.1957 | 0.1566 | 0.1296 | 0.1100 | 0.0951 | 0.0834 | 0.0740 | 0.0662 | 0.0598 | 0.0544 | 0.0497 | 0.0457 |
| **115** | | | 1.2528 | 0.6257 | 0.4169 | 0.3102 | 0.2451 | 0.2013 | 0.1699 | 0.1462 | 0.1278 | 0.1131 | 0.1011 | 0.0911 | 0.0827 | 0.0755 | 0.0693 |
| **120** | | | 3.0445 | 0.9680 | 0.6061 | 0.4394 | 0.3423 | 0.2786 | 0.2336 | 0.2002 | 0.1744 | 0.1539 | 0.1372 | 0.1234 | 0.1118 | 0.1020 | 0.0935 |
| **125** | | | | 1.4925 | 0.8398 | 0.5878 | 0.4499 | 0.3623 | 0.3017 | 0.2572 | 0.2231 | 0.1963 | 0.1747 | 0.1568 | 0.1419 | 0.1292 | 0.1183 |
| **130** | | | | 2.6626 | 1.1451 | 0.7621 | 0.5705 | 0.4537 | 0.3747 | 0.3176 | 0.2744 | 0.2407 | 0.2136 | 0.1914 | 0.1728 | 0.1572 | 0.1438 |
| **135** | | | | | 1.5870 | 0.9734 | 0.7077 | 0.5543 | 0.4535 | 0.3819 | 0.3285 | 0.2871 | 0.2541 | 0.2271 | 0.2048 | 0.1860 | 0.1699 |
| **140** | | | | | 2.3979 | 1.2417 | 0.8668 | 0.6662 | 0.5390 | 0.4507 | 0.3857 | 0.3358 | 0.2963 | 0.2643 | 0.2378 | 0.2156 | 0.1967 |
| **145** | | | | | | 1.6094 | 1.0561 | 0.7921 | 0.6325 | 0.5245 | 0.4463 | 0.3869 | 0.3403 | 0.3028 | 0.2719 | 0.2461 | 0.2243 |
| **150** | | | | | | 2.1972 | 1.2897 | 0.9362 | 0.7357 | 0.6042 | 0.5108 | 0.4408 | 0.3864 | 0.3429 | 0.3073 | 0.2776 | 0.2526 |
| **155** | | | | | | 3.8067 | 1.5950 | 1.1047 | 0.8508 | 0.6909 | 0.5798 | 0.4978 | 0.4347 | 0.3846 | 0.3439 | 0.3102 | 0.2817 |
| **160** | | | | | | | 2.0369 | 1.3074 | 0.9808 | 0.7857 | 0.6539 | 0.5583 | 0.4855 | 0.4282 | 0.3819 | 0.3438 | 0.3118 |
| **165** | | | | | | | 2.8478 | 1.5620 | 1.1304 | 0.8905 | 0.7340 | 0.6226 | 0.5390 | 0.4738 | 0.4215 | 0.3786 | 0.3427 |
| **170** | | | | | | | | 1.9042 | 1.3063 | 1.0076 | 0.8210 | 0.6914 | 0.5955 | 0.5215 | 0.4626 | 0.4146 | 0.3747 |
| **175** | | | | | | | | 2.4288 | 1.5198 | 1.1403 | 0.9163 | 0.7652 | 0.6554 | 0.5717 | 0.5055 | 0.4520 | 0.4077 |
| **180** | | | | | | | | 3.5988 | 1.7918 | 1.2933 | 1.0217 | 0.8449 | 0.7191 | 0.6244 | 0.5504 | 0.4908 | 0.4418 |
| **185** | | | | | | | | | 2.1665 | 1.4739 | 1.1394 | 0.9316 | 0.7872 | 0.6802 | 0.5974 | 0.5312 | 0.4772 |
| **190** | | | | | | | | | 2.7726 | 1.6946 | 1.2730 | 1.0264 | 0.8602 | 0.7392 | 0.6466 | 0.5733 | 0.5138 |
| **195** | | | | | | | | | 4.5643 | 1.9782 | 1.4271 | 1.1312 | 0.9390 | 0.8019 | 0.6985 | 0.6173 | 0.5518 |
| **200** | | | | | | | | | | 2.3755 | 1.6094 | 1.2483 | 1.0245 | 0.8688 | 0.7531 | 0.6633 | 0.5914 |

| I/IB<br>Es (%) | 1.85 | 1.90 | 1.95 | 2.00 | 2.20 | 2.40 | 2.60 | 2.80 | 3.00 | 3.20 | 3.40 | 3.60 | 3.80 | 4.00 | 4.20 | 4.40 | 4.60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **105** | 0.0209 | 0.0193 | 0.0180 | 0.0168 | 0.0131 | 0.0106 | 0.0087 | 0.0073 | 0.0063 | 0.0054 | 0.0047 | 0.0042 | 0.0037 | 0.0033 | 0.0030 | 0.0027 | 0.0025 |
| **110** | 0.0422 | 0.0391 | 0.0363 | 0.0339 | 0.0264 | 0.0212 | 0.0175 | 0.0147 | 0.0126 | 0.0109 | 0.0095 | 0.0084 | 0.0075 | 0.0067 | 0.0060 | 0.0055 | 0.0050 |
| **115** | 0.0639 | 0.0592 | 0.0550 | 0.0513 | 0.0398 | 0.0320 | 0.0264 | 0.0222 | 0.0189 | 0.0164 | 0.0143 | 0.0126 | 0.0112 | 0.0101 | 0.0091 | 0.0082 | 0.0075 |
| **120** | 0.0862 | 0.0797 | 0.0740 | 0.0690 | 0.0535 | 0.0429 | 0.0353 | 0.0297 | 0.0253 | 0.0219 | 0.0191 | 0.0169 | 0.0150 | 0.0134 | 0.0121 | 0.0110 | 0.0100 |
| **125** | 0.1089 | 0.1007 | 0.0934 | 0.0870 | 0.0673 | 0.0540 | 0.0444 | 0.0372 | 0.0317 | 0.0274 | 0.0240 | 0.0211 | 0.0188 | 0.0168 | 0.0151 | 0.0137 | 0.0125 |
| **130** | 0.1322 | 0.1221 | 0.1132 | 0.1054 | 0.0813 | 0.0651 | 0.0535 | 0.0449 | 0.0382 | 0.0330 | 0.0288 | 0.0254 | 0.0226 | 0.0202 | 0.0182 | 0.0165 | 0.0150 |
| **135** | 0.1560 | 0.1440 | 0.1334 | 0.1241 | 0.0956 | 0.0764 | 0.0627 | 0.0525 | 0.0447 | 0.0386 | 0.0337 | 0.0297 | 0.0264 | 0.0236 | 0.0213 | 0.0192 | 0.0175 |
| **140** | 0.1805 | 0.1664 | 0.1540 | 0.1431 | 0.1100 | 0.0878 | 0.0720 | 0.0603 | 0.0513 | 0.0443 | 0.0386 | 0.0340 | 0.0302 | 0.0270 | 0.0243 | 0.0220 | 0.0200 |
| **145** | 0.2055 | 0.1892 | 0.1750 | 0.1625 | 0.1246 | 0.0993 | 0.0813 | 0.0681 | 0.0579 | 0.0499 | 0.0435 | 0.0384 | 0.0341 | 0.0305 | 0.0274 | 0.0248 | 0.0226 |
| **150** | 0.2312 | 0.2127 | 0.1965 | 0.1823 | 0.1395 | 0.1110 | 0.0908 | 0.0759 | 0.0645 | 0.0556 | 0.0485 | 0.0427 | 0.0379 | 0.0339 | 0.0305 | 0.0276 | 0.0251 |
| **155** | 0.2575 | 0.2366 | 0.2185 | 0.2025 | 0.1546 | 0.1228 | 0.1004 | 0.0838 | 0.0712 | 0.0614 | 0.0535 | 0.0471 | 0.0418 | 0.0374 | 0.0336 | 0.0304 | 0.0277 |
| **160** | 0.2846 | 0.2612 | 0.2409 | 0.2231 | 0.1699 | 0.1347 | 0.1100 | 0.0918 | 0.0780 | 0.0671 | 0.0585 | 0.0515 | 0.0457 | 0.0408 | 0.0367 | 0.0332 | 0.0302 |
| **165** | 0.3124 | 0.2864 | 0.2639 | 0.2442 | 0.1855 | 0.1468 | 0.1197 | 0.0999 | 0.0847 | 0.0729 | 0.0635 | 0.0559 | 0.0496 | 0.0443 | 0.0398 | 0.0360 | 0.0328 |
| **170** | 0.3410 | 0.3122 | 0.2874 | 0.2657 | 0.2012 | 0.1591 | 0.1296 | 0.1080 | 0.0916 | 0.0788 | 0.0686 | 0.0603 | 0.0535 | 0.0478 | 0.0430 | 0.0389 | 0.0353 |
| **175** | 0.3705 | 0.3388 | 0.3115 | 0.2877 | 0.2173 | 0.1715 | 0.1395 | 0.1161 | 0.0984 | 0.0847 | 0.0737 | 0.0648 | 0.0574 | 0.0513 | 0.0461 | 0.0417 | 0.0379 |
| **180** | 0.4008 | 0.3660 | 0.3361 | 0.3102 | 0.2336 | 0.1840 | 0.1495 | 0.1244 | 0.1054 | 0.0906 | 0.0788 | 0.0692 | 0.0614 | 0.0548 | 0.0493 | 0.0446 | 0.0405 |
| **185** | 0.4321 | 0.3940 | 0.3614 | 0.3331 | 0.2502 | 0.1967 | 0.1597 | 0.1327 | 0.1123 | 0.0965 | 0.0839 | 0.0737 | 0.0653 | 0.0583 | 0.0524 | 0.0474 | 0.0431 |
| **190** | 0.4644 | 0.4229 | 0.3873 | 0.3567 | 0.2671 | 0.2096 | 0.1699 | 0.1411 | 0.1193 | 0.1025 | 0.0891 | 0.0782 | 0.0693 | 0.0619 | 0.0556 | 0.0503 | 0.0457 |
| **195** | 0.4978 | 0.4525 | 0.4140 | 0.3808 | 0.2842 | 0.2226 | 0.1802 | 0.1495 | 0.1264 | 0.1085 | 0.0943 | 0.0828 | 0.0733 | 0.0654 | 0.0588 | 0.0531 | 0.0483 |
| **200** | 0.5324 | 0.4831 | 0.4413 | 0.4055 | 0.3017 | 0.2358 | 0.1907 | 0.1581 | 0.1335 | 0.1145 | 0.0995 | 0.0873 | 0.0773 | 0.0690 | 0.0620 | 0.0560 | 0.0509 |

### Hot Curves

| I/IB | 4.80 | 5.00 | 5.50 | 6.00 | 6.50 | 7.00 | 7.50 | 8.00 | 8.50 | 9.00 | 9.50 | 10.00 | 12.50 | 15.00 | 17.50 | 20.00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Es (%)** | | | | | | | | | | | | | | | | |
| **105** | 0.0023 | 0.0021 | 0.0017 | 0.0014 | 0.0012 | 0.0010 | 0.0009 | 0.0008 | 0.0007 | 0.0006 | 0.0006 | 0.0005 | 0.0003 | 0.0002 | 0.0002 | 0.0001 |
| **110** | 0.0045 | 0.0042 | 0.0034 | 0.0029 | 0.0024 | 0.0021 | 0.0018 | 0.0016 | 0.0014 | 0.0013 | 0.0011 | 0.0010 | 0.0006 | 0.0004 | 0.0003 | 0.0003 |
| **115** | 0.0068 | 0.0063 | 0.0051 | 0.0043 | 0.0036 | 0.0031 | 0.0027 | 0.0024 | 0.0021 | 0.0019 | 0.0017 | 0.0015 | 0.0010 | 0.0007 | 0.0005 | 0.0004 |
| **120** | 0.0091 | 0.0084 | 0.0069 | 0.0057 | 0.0049 | 0.0042 | 0.0036 | 0.0032 | 0.0028 | 0.0025 | 0.0022 | 0.0020 | 0.0013 | 0.0009 | 0.0007 | 0.0005 |
| **125** | 0.0114 | 0.0105 | 0.0086 | 0.0072 | 0.0061 | 0.0052 | 0.0045 | 0.0040 | 0.0035 | 0.0031 | 0.0028 | 0.0025 | 0.0016 | 0.0011 | 0.0008 | 0.0006 |
| **130** | 0.0137 | 0.0126 | 0.0103 | 0.0086 | 0.0073 | 0.0063 | 0.0054 | 0.0048 | 0.0042 | 0.0038 | 0.0034 | 0.0030 | 0.0019 | 0.0013 | 0.0010 | 0.0008 |
| **135** | 0.0160 | 0.0147 | 0.0120 | 0.0101 | 0.0085 | 0.0073 | 0.0064 | 0.0056 | 0.0049 | 0.0044 | 0.0039 | 0.0035 | 0.0023 | 0.0016 | 0.0011 | 0.0009 |
| **140** | 0.0183 | 0.0168 | 0.0138 | 0.0115 | 0.0097 | 0.0084 | 0.0073 | 0.0064 | 0.0056 | 0.0050 | 0.0045 | 0.0040 | 0.0026 | 0.0018 | 0.0013 | 0.0010 |
| **145** | 0.0206 | 0.0189 | 0.0155 | 0.0129 | 0.0110 | 0.0094 | 0.0082 | 0.0072 | 0.0063 | 0.0056 | 0.0051 | 0.0046 | 0.0029 | 0.0020 | 0.0015 | 0.0011 |
| **150** | 0.0229 | 0.0211 | 0.0172 | 0.0144 | 0.0122 | 0.0105 | 0.0091 | 0.0080 | 0.0070 | 0.0063 | 0.0056 | 0.0051 | 0.0032 | 0.0022 | 0.0016 | 0.0013 |
| **155** | 0.0253 | 0.0232 | 0.0190 | 0.0158 | 0.0134 | 0.0115 | 0.0100 | 0.0088 | 0.0077 | 0.0069 | 0.0062 | 0.0056 | 0.0035 | 0.0025 | 0.0018 | 0.0014 |
| **160** | 0.0276 | 0.0253 | 0.0207 | 0.0173 | 0.0147 | 0.0126 | 0.0109 | 0.0096 | 0.0085 | 0.0075 | 0.0067 | 0.0061 | 0.0039 | 0.0027 | 0.0020 | 0.0015 |
| **165** | 0.0299 | 0.0275 | 0.0225 | 0.0187 | 0.0159 | 0.0136 | 0.0118 | 0.0104 | 0.0092 | 0.0082 | 0.0073 | 0.0066 | 0.0042 | 0.0029 | 0.0021 | 0.0016 |
| **170** | 0.0323 | 0.0296 | 0.0242 | 0.0202 | 0.0171 | 0.0147 | 0.0128 | 0.0112 | 0.0099 | 0.0088 | 0.0079 | 0.0071 | 0.0045 | 0.0031 | 0.0023 | 0.0018 |
| **175** | 0.0346 | 0.0317 | 0.0260 | 0.0217 | 0.0183 | 0.0157 | 0.0137 | 0.0120 | 0.0106 | 0.0094 | 0.0084 | 0.0076 | 0.0048 | 0.0034 | 0.0025 | 0.0019 |
| **180** | 0.0370 | 0.0339 | 0.0277 | 0.0231 | 0.0196 | 0.0168 | 0.0146 | 0.0128 | 0.0113 | 0.0101 | 0.0090 | 0.0081 | 0.0052 | 0.0036 | 0.0026 | 0.0020 |
| **185** | 0.0393 | 0.0361 | 0.0295 | 0.0246 | 0.0208 | 0.0179 | 0.0155 | 0.0136 | 0.0120 | 0.0107 | 0.0096 | 0.0086 | 0.0055 | 0.0038 | 0.0028 | 0.0021 |
| **190** | 0.0417 | 0.0382 | 0.0313 | 0.0261 | 0.0221 | 0.0189 | 0.0164 | 0.0144 | 0.0127 | 0.0113 | 0.0101 | 0.0091 | 0.0058 | 0.0040 | 0.0030 | 0.0023 |
| **195** | 0.0441 | 0.0404 | 0.0330 | 0.0275 | 0.0233 | 0.0200 | 0.0173 | 0.0152 | 0.0134 | 0.0119 | 0.0107 | 0.0096 | 0.0061 | 0.0043 | 0.0031 | 0.0024 |
| **200** | 0.0464 | 0.0426 | 0.0348 | 0.0290 | 0.0245 | 0.0211 | 0.0183 | 0.0160 | 0.0141 | 0.0126 | 0.0113 | 0.0102 | 0.0065 | 0.0045 | 0.0033 | 0.0025 |

# Breaker Failure
ANSI Code 50BF

*Backup protection if the circuit breaker does not trip.*

## Description

If a breaker fails to open after a tripping command (detected by the non-extinction of the fault current), this backup protection sends a tripping command to upstream or adjacent breakers.

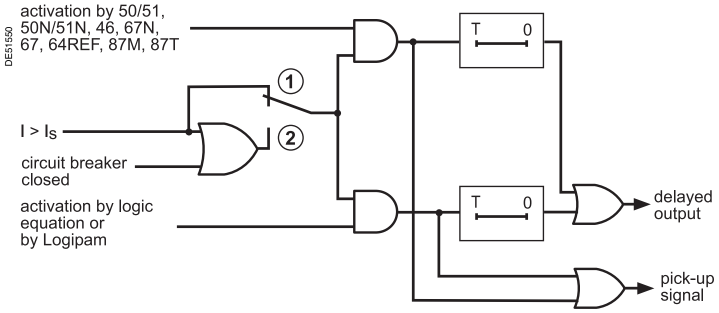
The "breaker failure" protection function is activated by an O1 output tripping command received from the overcurrent protection functions which trip the circuit breaker (50/51, 50N/51N, 46, 67N, 67, 64REF, 87M, 87T). It checks for the absence of current during the time interval specified by the time delay T. It may also take into account the position of the circuit breaker, read on the logic inputs to determine the actual opening of the breaker.

Automatic activation of this protection function requires the use of the circuit breaker control function in the control logic. A specific input can also be used to activate the protection by logic equation or by Logipam. That option is useful for adding special cases of activation (e.g. tripping by an external protection unit).

The time-delayed output of the protection function should be assigned to a logic output via the control matrix.

Starting and stopping of the time delay T counter are conditioned by the presence of a current above the set point (I > Is).

## Block Diagram


DE51550
activation by 50/51, 50N/51N, 46, 67N, 67, 64REF, 87M, 87T
①
②
I > Is
circuit breaker closed
activation by logic equation or by Logipam
T 0
T 0
delayed output
pick-up signal

*Setting:* ① *without considering circuit breaker position*
② *considering circuit breaker position*

## Characteristics

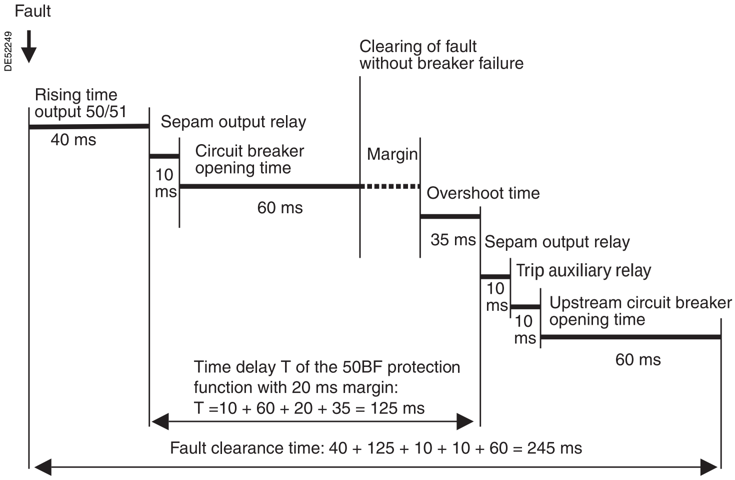
| | | | | |
|---|---|---|---|---|
| **Settings** | | | | |
| **Is Set Point** | | | | |
| Setting range | 0.2 IN to 2 IN | | | |
| Accuracy (1) | ±5% | | | |
| Resolution | 0.1 A | | | |
| Drop out/pick up ratio | 87.5% ±2% | | | |
| **Time Delay T** | | | | |
| Setting range | 50 ms to 3 s | | | |
| Accuracy (1) | ±2% or -10 ms to +15 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Considering Circuit Breaker Position** | | | | |
| Setting range | With / without | | | |
| **Characteristic Times** | | | | |
| Overshoot time | < 35 ms at 2 Is | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P50BF_1_101 | ■ | ■ | |
| Start 50BF | P50BF_1_107 | ■ | ■ | |
| Protection blocking | P50BF_1_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P50BF_1_1 | ■ | ■ | |
| Delayed output | P50BF_1_3 | ■ | ■ | ■ |
| Protection blocked | P50BF_1_16 | ■ | ■ | |

***(1)** Under reference conditions (IEC 60255-6).*

### Example

Below is an example for determining the time-delay setting of the breaker failure function. The following parameters are for the illustration:

- overcurrent protection setting: T = inst
- circuit breaker operating time: 60 ms
- auxiliary relay operating time to open the upstream breaker(s): 10 ms.


DE52249
Fault
Clearing of fault without breaker failure
Rising time output 50/51
40 ms
Sepam output relay
10 ms
Circuit breaker opening time
60 ms
Margin
Overshoot time
35 ms
Sepam output relay
10 ms
Trip auxiliary relay
10 ms
Upstream circuit breaker opening time
60 ms
Time delay T of the 50BF protection function with 20 ms margin:
T =10 + 60 + 20 + 35 = 125 ms
Fault clearance time: 40 + 125 + 10 + 10 + 60 = 245 ms

The breaker failure function time delay is the sum of the following times:

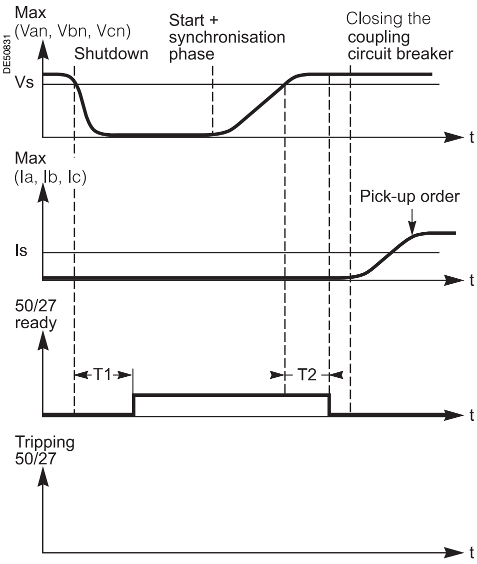
- Sepam™ O1 output relay pick-up time = 10 ms
- circuit breaker opening time = 60 ms
- Breaker failure function overshoot time = 35 ms.

To avoid unwanted tripping of the upstream breakers, add a margin of approximately 20 ms.

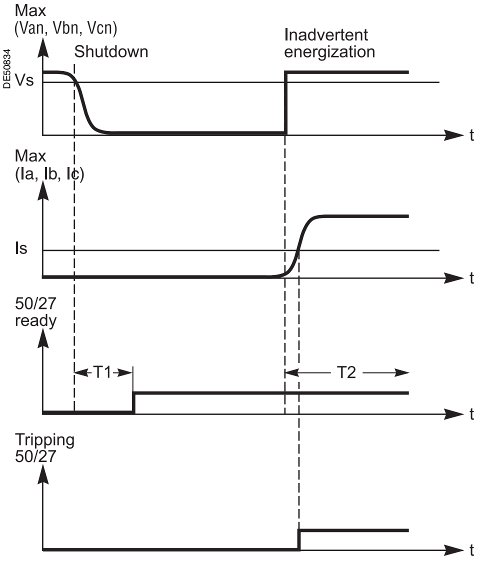
The time delay is 125 ms minimum, set at 130 ms.

# Inadvertent Energization
ANSI Code 50/27

*Protection against inadvertent energization of generators that are shut down.*



*Example: Generator shutdown and normal starting.*



*Example: Generator shutdown and inadvertent starting.*

## Description

The protection function checks the generator starting sequence to detect inadvertent energization of generators that are shut down.
A generator which is energized when shut down operates like a motor. A starting current occurs and produces significant heat rise that can damage machine windings.

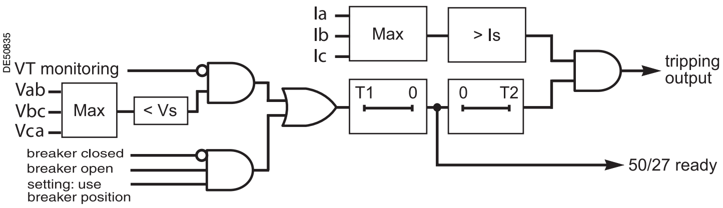
The check on the generator starting sequence is carried out by an instantaneous phase overcurrent protection function, confirmed by an undervoltage protection function. The undervoltage protection function is set up with:

- an on time delay T1 to make the function insensitive to voltage sags
- a timer hold T2 during which the function detects a generator starting current caused by inadvertent energization.

By taking into account the circuit-breaker position, it is possible to check the quality of synchronization. If the voltage and frequency differences are too high when the circuit breaker closes, a current immediately appears that the element detects.

When the VT monitoring detects a measurement problem on the voltage channels, the part concerning the voltages is blocked.

## Block Diagram



## Characteristics

| | | | | |
|---|---|---|---|---|
| **Settings** | | | | |
| **Current Set Point** | | | | |
| Setting range | 0.5 to 4 $I_N$ | | | |
| Accuracy (1) | ±5% or 0.02 $I_N$ | | | |
| Resolution | 1 A | | | |
| Drop out/pick up ratio | 95.5% or 0.015 $I_N$ | | | |
| **Voltage Set Point** | | | | |
| Setting range | 10% to 100% of $V_{LL}$ | | | |
| Accuracy (1) | ±2% or 0.005 $V_{LLp}$ | | | |
| Resolution | 1% | | | |
| Drop out/pick up ratio | 103% | | | |
| **Advanced Settings** | | | | |
| **Use of Breaker Position** | | | | |
| Setting range | Used / not used | | | |
| **T1 Time** | | | | |
| Setting range | 0 to 10 s | | | |
| Accuracy (1) | ±2% or from -10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **T2 Time** | | | | |
| Setting range | 0 to 10 s | | | |
| Accuracy (1) | ±2% or from -10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Characteristic times (1)** | | | | |
| Operation time | < 40 ms at 2 Is (typically 30 ms) | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P50/27_1_101 | ■ | ■ | |
| Protection blocking | P50/27_1_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Tripping output | P50/27_1_3 | ■ | ■ | ■ |
| Protection blocked | P50/27_1_16 | ■ | ■ | |
| Protection ready | P50/27_1_35 | ■ | ■ | |

***(1)** Under reference conditions (IEC 60255-6).*

## Example

**Synchronous generator data**

- S = 3.15 MVA
- $V_{LL}N1$ = 6.3 kV
- Xd = 233%
- X'd = 21%
- X''d = 15%
- the generator is connected to a network with a Psc = 10 MVA
- the maximum admissible duration of a voltage sag is 2.5 seconds.

To set the protection function, it is necessary to calculate the rated generator impedance:

- $IB = S/(\sqrt{3}\, V_{LL}N1) = 289$ A
- $Z_N = V_{LL}N1/(\sqrt{3}\, IB) = 12.59\ \Omega$.

The network impedance is:
$Zpsc = (V_{LL}N1)^2/Psc = 3.97\ \Omega$.

The Istart starting current is approximately:

$$\mathrm{Istart} = \frac{V_{LL}N1}{\sqrt{3}\left(Zpsc + \frac{X'd}{100} \times Z_N\right)} = 621\ \mathrm{A} \quad .$$

The current set point is set between 20% and 50% of the starting current.

$$\mathrm{Is} = 0.5 \times \mathrm{Istart} \approx 311\ \mathrm{A}$$

The voltage set point is often set between 80% and 85% of $V_{LL}N$. In this example, the selected set point is $V_{LL}s$ = 85%.

The T1 time is set longer than the maximum admissible duration of a voltage sag, e.g. T1 = 4 sec.

T2 is set to detect the appearance of a current during starting.
For example, T2 = 250 ms.

# Phase Overcurrent
## ANSI Code 50/51

*Protection against overcurrents and overloads.*

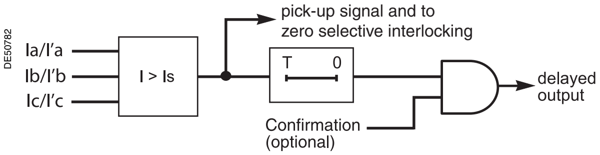
### Description

Protection against overcurrents and overloads:

- the protection function is three-phase and has a definite or IDMT time delay
- each of the eight units has two groups of settings. Switching to setting group A or B can be carried out by a logic input or a remote control command, depending on the settings
- for better detection of distant faults, the protection function can be confirmed by:
  - ☐ undervoltage protection unit 1 or
  - ☐ negative sequence overvoltage protection unit 1
- the customized curve, defined point by point, may be used with this protection function
- an adjustable timer hold, definite time or IDMT, can be used for coordination with electromagnetic relays and to detect restriking faults.
- Set IDMT Trip Curves by Time delay T (at $I/I_{set} = 10$) or TMS Factor ( like Time Dial Setting) - refer to topic "General Trip Curves at the end of this section

| Tripping Curve | Timer Hold |
|---|---|
| Definite time (DT) | Definite time |
| Standard inverse time (SIT) | Definite time |
| Very inverse time (VIT or LTI) | Definite time |
| Extremely inverse time (EIT) | Definite time |
| Ultra inverse time (UIT) | Definite time |
| RI curve | Definite time |
| IEC inverse time SIT / A | Definite time or IDMT |
| IEC very inverse time VIT or LTI / B | Definite time or IDMT |
| IEC extremely inverse time EIT / C | Definite time or IDMT |
| IEEE moderately inverse (IEC / D) | Definite time or IDMT |
| IEEE very inverse (IEC / E) | Definite time or IDMT |
| IEEE extremely inverse (IEC / F) | Definite time or IDMT |
| IAC inverse | Definite time or IDMT |
| IAC very inverse | Definite time or IDMT |
| IAC extremely inverse | Definite time or IDMT |
| Customized | Definite time |

### Block Diagram



# Phase Overcurrent
## ANSI Code 50/51

### Characteristics

| **Settings** | | |
|---|---|---|
| **Measurement Origin** | | |
| Setting range | Main channels (I) / Additional channels (I’) | |
| **Tripping Curve** | | |
| Setting range | See previous page | |
| **Is Set Point** | | |
| Setting range | Definite time | 0.05 IN ≤ Is ≤ 24 IN expressed in amperes |
| | IDMT | 0.05 IN ≤ Is ≤ 2.4 IN expressed in amperes |
| Accuracy (1) | ±5% or ±0.01 IN | |
| Resolution | 1 A or 1 digit | |
| Drop out/pick up ratio | 93.5% ±5% or > (1 - 0.015 IN/Is) x 100% | |
| **Time Delay T (Operation Time at 10 Is)** | | |
| Setting range | Definite time | Inst, 50 ms ≤ T ≤ 300 s |
| | IDMT | 100 ms ≤ T ≤ 12.5 s or TMS (2) |
| Accuracy (1) | Definite time | ±2% or from –10 ms to +25 ms |
| | IDMT | Class 5 or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit | |
| **Advanced Settings** | | |
| **Confirmation** | | |
| Setting range | By undervoltage (unit 1)<br>By negative sequence overvoltage (unit 1)<br>None, no confirmation | |
| **Timer Hold T1** | | |
| Setting range | Definite time | 0; 0.05 to 300 s |
| | IDMT (3) | 0.5 to 20 s |
| Resolution | 10 ms or 1 digit | |
| **Characteristic Times** | | |
| Operation time | pick-up < 35 ms at 2 Is (typically 25 ms)<br>Inst. < 50 ms at 2 Is (confirmed instantaneous) (typically 35 ms) | |
| Overshoot time | < 50 ms at 2 Is | |
| Reset time | < 50 ms at 2 Is (for T1 = 0) | |

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Protection reset | P50/51_x_101 | ■ | ■ |
| Protection blocking | P50/51_x_113 | ■ | ■ |

**Outputs**

| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Instantaneous output (pick-up) | P50/51_x_1 | ■ | ■ | |
| Delayed output | P50/51_x_3 | ■ | ■ | ■ |
| Drop out | P50/51_x_4 | ■ | ■ | |
| Phase "a" fault | P50/51_x_7 | ■ | ■ | |
| Phase "b" fault | P50/51_x_8 | ■ | ■ | |
| Phase "c" fault | P50/51_x_9 | ■ | ■ | |
| Protection blocked | P50/51_x_16 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

***(2)** Setting ranges in TMS (Time Multiplier Setting) mode*

- *Inverse (SIT) and IEC SIT/A: 0.04 to 4.20*
- *Very inverse (VIT) and IEC VIT/B: 0.07 to 8.33*
- *Very inverse (LTI) and IEC LTI/B: 0.01 to 0.93*
- *Ext. inverse (EIT) and IEC EIT/C: 0.13 to 15.47*
- *IEEE moderately inverse: 0.42 to 51.86*
- *IEEE very inverse: 0.73 to 90.57*
- *IEEE extremely inverse: 1.24 to 154.32*
- *IAC inverse: 0.34 to 42.08*
- *IAC very inverse: 0.61 to 75.75*
- *IAC extremely inverse: 1.08 to 134.4.*

***(3)** Only for standardized tripping curves of the IEC, IEEE and IAC types.*

# Ground Fault
## ANSI Code 50N/51N or 50G/51G

*Protection against ground faults.*

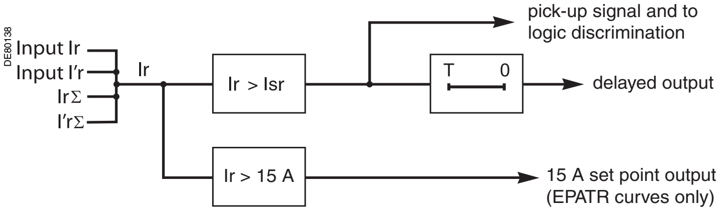
## Description

Ground fault protection based on measured neutral, zero sequence or ground fault (tank ground leakage protection) current:

- the protection function has a definite or IDMT time delay
- each of the eight units has two groups of settings. Switching to setting group A or B can be carried out by a logic input or a remote control command, depending on the settings
- The protection function includes settable second harmonic restraint which provides greater stability when transformers are energized.
- the customized curve, defined point by point, may be used with this protection function
- an adjustable timer hold, definite or IDMT, can be used for coordination with electromagnetic relays and to detect restriking faults
- each unit can be independently set to one of the two measurement channels Ir or I'r or to the sum of the phase currents on the main or additional channels. By mixing the possibilities on the different units, it is possible to have:
  - ☐ different dynamic set points
  - ☐ different applications, like zero sequence and tank ground leakage protection.
- Set IDMT Trip Curves by Time delay T (at $I/I_{set} = 10$) or TMS Factor ( like Time Dial Setting) - refer to topic "General Trip Curves at the end of this section

| Tripping Curve | Timer Hold Curve |
|---|---|
| Definite time (DT) | Definite time |
| Standard inverse time (SIT) | Definite time |
| Very inverse time (VIT or LTI) | Definite time |
| Extremely inverse time (EIT) | Definite time |
| Ultra inverse time (UIT) | Definite time |
| RI curve | Definite time |
| IEC inverse time SIT / A | Definite time or IDMT |
| IEC very inverse time VIT or LTI / B | Definite time or IDMT |
| IEC extremely inverse time EIT / C | Definite time or IDMT |
| IEEE moderately inverse (IEC / D) | Definite time or IDMT |
| IEEE very inverse (IEC / E) | Definite time or IDMT |
| IEEE extremely inverse (IEC / F) | Definite time or IDMT |
| IAC inverse | Definite time or IDMT |
| IAC very inverse | Definite time or IDMT |
| IAC extremely inverse | Definite time or IDMT |
| EPATR-B | Definite time |
| EPATR-C | Definite time |
| Customized | Definite time |

## Block Diagram

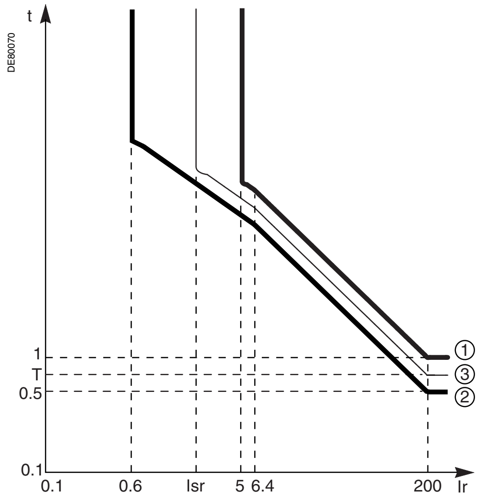

DE80138
Input Ir
Input I'r
IrΣ
I'rΣ
Ir
Ir > Isr
pick-up signal and to logic discrimination
T 0
delayed output
Ir > 15 A
15 A set point output (EPATR curves only)

## Ground Fault
## ANSI Code 50N/51N or 50G/51G

### EPATR-B curves

EPATR-B tripping curves are defined from the following equations:

- for Isr ≤ Ir ≤ 6.4 A $\quad \mathbf{t = \frac{85.386}{I0^{0.708}} \times \frac{T}{0.8}}$
- if 6.4A ≤ Ir ≤ 200A $\quad \mathbf{= \frac{140.213}{I0^{0.975}} \times \frac{T}{0.8}}$
- for Ir > 200 A $\quad \mathbf{t = T}$



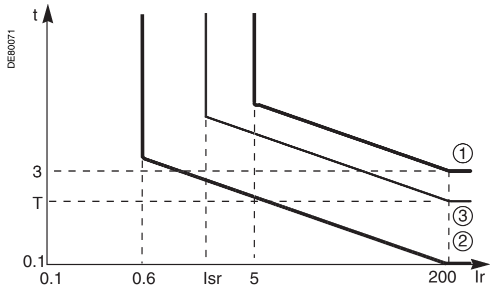
*EPATR-B standard curve (log scales)*

*Curve ① : Isr = 5 A and T = 1 s*
*Curve ② : Isr = 0.6 A and T = 0.5 s*
*Curve ③ : Isr and T*

### EPATR-C Curves

EPATR-C tripping curves are defined from the following equations:

- for Isr ≤ Ir ≤ 200 A $\quad \mathbf{t = \frac{72}{I0^{2/3}} \times \frac{T}{2.10}}$
- for Ir > 200 A $\quad \mathbf{t = T}$



*EPATR-C standard curve (log scales)*

*Curve ①: Isr = 5 A and T = 3 s*
*Curve ②: Isr = 0.6 A and T = 0.1 s*
*Curve ③: Isr and T*

# Ground Fault
## ANSI Code 50N/51N or 50G/51G

### Characteristics

| **Settings** | | |
|---|---|---|
| **Measurement Origin** | | |
| Setting range | Ir<br>I'r<br>IrΣ (sum of the main phase channels)<br>I'rΣ (sum of the additional phase channels) | |
| **Tripping Curve** | | |
| Setting range | See previous page | |
| **Isr Setting** | | |
| Definite time<br>Setting range | 0.01 INr ≤ Isr ≤ 15 INr (min. 0.1 A) expressed in amperes | |
| | Sum of CTs | 0.01 IN ≤ Isr ≤ 15 IN (min. 0.1 A) |
| | With CSH sensor | |
| | 2 A rating | 0.1 to 30 A |
| | 20 A rating | 0.2 to 300 A |
| | CT | 0.01 INr ≤ Isr ≤ 15 INr (min. 0.1 A) |
| | Zero sequence CT + ACE990 | 0.01 INr ≤ Isr ≤ 15 INr (min. 0.1 A) |
| IDMT<br>Setting range | 0.01 INr ≤ Isr ≤ INr (min. 0.1 A) expressed in amperes | |
| | Sum of CTs | 0.01 IN ≤ Isr ≤ IN (min. 0.1 A) |
| | With CSH sensor | |
| | 2 A rating | 0.1 to 2 A |
| | 20 A rating | 0.2 to 20 A |
| | CT | 0.01 INr ≤ Isr ≤ INr (min. 0.1 A) |
| | Zero sequence CT + ACE990 | 0.01 INr ≤ Isr ≤ INr (min. 0.1 A) |
| EPATR<br>Setting range | CSH sensor 20 A rating | 0.6 to 5 A |
| | Zero sequence CT with ACE990 and 15 A ≤ INr ≤ 50 A | 0.6 to 5 A |
| Accuracy (1) | ±5% or ±0.004 In0 | |
| Resolution | 1 A or 1 digit | |
| Drop out/pick up ratio | 93.5% ±5% or > (1 - 0.005 INr/Isr) x 100% | |
| **Time Delay T (Operation Time at 10 Isr)** | | |
| Setting range | Definite time | Inst, 50 ms ≤ T ≤ 300 s |
| | IDMT | 100 ms ≤ T ≤ 12.5 s or TMS (2) |
| | EPATR-B | 0.5 to 1 s |
| | EPATR-C | 0.1 to 3 s |
| Accuracy (1) | Definite time | ±2% or from –10 ms to +25 ms |
| | IDMT | Class 5 or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit | |
| **Advanced Settings** | | |
| **2nd Harmonic Restraint** | | |
| Fixed threshold | 17% ±3% | |
| **Timer Hold T1** | | |
| Setting range | Definite time | 0; 0.05 to 300 s |
| | IDMT (3) | 0.5 to 20 s |
| Resolution | 10 ms or 1 digit | |
| **Characteristic Times** | | |
| Operation time | Pick-up < 40 ms at 2 Isr (typically 25 ms)<br>Confirmed instantaneous:<br>■ inst < 55 ms at 2 Isr for Is ≥ 0.3 INr (typically 35 ms)<br>■ inst < 70 ms at 2 Isr for Is < 0.3 INr (typically 50 ms) | |
| Overshoot time | < 40 ms at 2 Isr | |
| Reset time | < 50 ms at 2 Isr (for T1 = 0) | |

**Inputs**

| **Designation** | **Syntax** | **Equations** | **Logipam** |
|---|---|---|---|
| Protection reset | P50N/51N_x_101 | ■ | ■ |
| Protection blocking | P50N/51N_x_113 | ■ | ■ |

**Outputs**

| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
|---|---|---|---|---|
| Instantaneous output (pick-up) | P50N/51N_x_1 | ■ | ■ | |
| Delayed output | P50N/51N_x_3 | ■ | ■ | ■ |
| Drop out | P50N/51N_x_4 | ■ | ■ | |
| Protection blocked | P50N/51N_x_16 | ■ | ■ | |
| 15 A set point output | P50N/51N_x_56 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

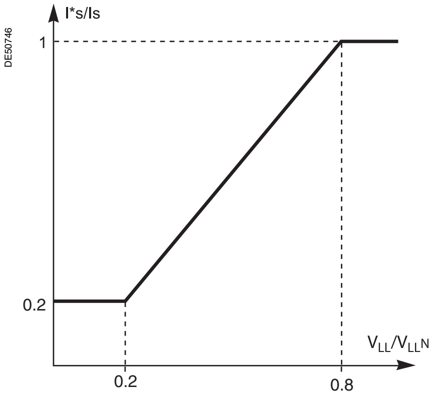
***(2)** Setting ranges in TMS (Time Multiplier Setting) mode*

- *Inverse (SIT) and IEC SIT/A: 0.04 to 4.20*
- *Very inverse (VIT) and IEC VIT/B: 0.07 to 8.33*
- *Very inverse (LTI) and IEC LTI/B: 0.01 to 0.93*
- *Ext. inverse (EIT) and IEC EIT/C: 0.13 to 15.47*
- *IEEE moderately inverse: 0.42 to 51.86*
- *IEEE very inverse: 0.73 to 90.57*
- *IEEE extremely inverse: 1.24 to 154.32*
- *IAC inverse: 0.34 to 42.08*
- *IAC very inverse: 0.61 to 75.75*
- *IAC extremely inverse: 1.08 to 134.4.*

***(3)** Only for standardized tripping curves of the IEC, IEEE and IAC types.*

# Voltage-Restrained Overcurrent
## ANSI Code 50V/51V

*Generator protection against close short-circuits.*



*Set point adjustment.*

## Description

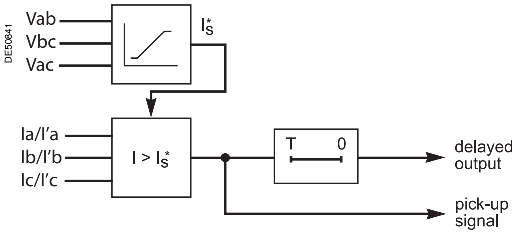
The voltage-restrained overcurrent protection function is used to protect generators. The operation set point is adjusted according to the voltage to take into account cases of faults close to the generator which cause voltage dips and short-circuit current:

- the protection function is three-phase and has a definite or IDMT time delay
- the customized curve, defined point by point, may be used with this protection function
- an adjustable timer hold, definite time or IDMT, can be used for coordination with electromagnetic relays and to detect restriking faults
- the set point is adjusted according to the lowest of the phase-to-phase voltages measured. The adjusted set point $I_s^*$ is defined by the following equation:
- Set IDMT Trip Curves by Time delay T (at $I/I_{set} = 10$) or TMS Factor ( like Time Dial Setting) - refer to topic "General Trip Curves at the end of this section

$$I_s^* = \frac{Is}{3} \times \left(4\frac{V_{LL}}{V_{LLN}} - 0.2\right)$$

| Trip Curve | Timer Hold |
|---|---|
| Definite time (DT) | Definite time |
| Standard inverse time (SIT) | Definite time |
| Very inverse time (VIT or LTI) | Definite time |
| Extremely inverse time (EIT) | Definite time |
| Ultra inverse time (UIT) | Definite time |
| RI curve | Definite time |
| IEC inverse time SIT / A | Definite time or IDMT |
| IEC very inverse time VIT or LTI / B | Definite time or IDMT |
| IEC extremely inverse time EIT / C | Definite time or IDMT |
| IEEE moderately inverse (IEC / D) | Definite time or IDMT |
| IEEE very inverse (IEC / E) | Definite time or IDMT |
| IEEE extremely inverse (IEC / F) | Definite time or IDMT |
| IAC inverse | Definite time or IDMT |
| IAC very inverse | Definite time or IDMT |
| IAC extremely inverse | Definite time or IDMT |
| Customized | Definite time |

## Block Diagram



# Voltage-Restrained Overcurrent
ANSI Code 50V/51V

## Characteristics

| | | |
|---|---|---|
| **Settings** | | |
| **Measurement Origin** | | |
| Setting range | Main channels (I) / Additional channels (I’) | |
| **Tripping Curve** | | |
| Setting range | See previous page | |
| **Is Set Point** | | |
| Setting range | Definite time | 0.5 IN ≤ Is ≤ 24 IN expressed in amperes |
| | IDMT | 0.5 IN ≤ Is ≤ 2.4 IN expressed in amperes |
| Accuracy (1) | ±5% | |
| Resolution | 1 A or 1 digit | |
| Drop out/pick up ratio | 93.5% (with min. reset variance of 0.015 IN) | |
| **Time Delay T (Operation Time at 10 Is)** | | |
| Setting range | Definite time | Inst, 50 ms ≤ T ≤ 300 s |
| | IDMT | 100 ms ≤ T ≤ 12.5 s or TMS (2) |
| Accuracy (1) | Definite time | ±2% or from –10 ms to +25 ms |
| | IDMT | Class 5 or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit | |
| **Advanced Settings** | | |
| **Timer Hold T1** | | |
| Setting range | Definite time | 0; 0.05 to 300 s |
| | IDMT time (3) | 0.5 to 20 s |
| Resolution | 10 ms or 1 digit | |
| **Characteristic Times** | | |
| Operation time | pick-up < 35 ms at 2 Is (typically 25 ms)<br>Inst. < 50 ms at 2 Is (confirmed instantaneous) (typically 35 ms) | |
| Overshoot time | < 50 ms | |
| Reset time | < 50 ms (for T1 = 0) | |

**Inputs**

| **Designation** | **Syntax** | **Equations** | **Logipam** |
|---|---|---|---|
| Protection reset | P50V/51V_x_101 | ■ | ■ |
| Protection blocking | P50V/51V_x_113 | ■ | ■ |

**Outputs**

| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
|---|---|---|---|---|
| Instantaneous output (pick-up) | P50V/51V_x_1 | ■ | ■ | |
| Delayed output | P50V/51V_x_3 | ■ | ■ | ■ |
| Drop out | P50V/51V_x_4 | ■ | ■ | |
| Phase a fault | P50V/51V_x_7 | ■ | ■ | |
| Phase b fault | P50V/51V_x_8 | ■ | ■ | |
| Phase c fault | P50V/51V_x_9 | ■ | ■ | |
| Protection blocked | P50V/51V_x_16 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

***(2)** Setting ranges in TMS (Time Multiplier Setting) mode*

- *Inverse (SIT) and IEC SIT/A: 0.04 to 4.20*
- Very inverse (VIT) and IEC VIT/B: 0.07 to 8.33
- Very inverse (LTI) and IEC LTI/B: 0.01 to 0.93
- *Ext. inverse (EIT) and IEC EIT/C: 0.13 to 15.47*
- IEEE moderately inverse: 0.42 to 51.86
- *IEEE very inverse: 0.73 to 90.57*
- IEEE extremely inverse: 1.24 to 154.32
- *IAC inverse: 0.34 to 42.08*
- *IAC very inverse: 0.61 to 75.75*
- *IAC extremely inverse: 1.08 to 134.4.*

***(3)** Only for standardized tripping curves of the IEC, IEEE and IAC types.*

# Capacitor Bank Unbalance
ANSI Code 51C

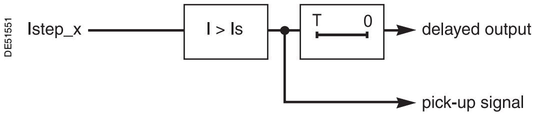
*Detection of capacitor bank internal faults by measurement of the unbalance current flowing between the two neutral points of a double-wye connected capacitor bank.*

## Description

The capacitor bank unbalance function detects unbalance current flowing between the two neutral points of double-wye connected capacitor banks.

The protection function is activated when the unbalance current is higher than the current set point (Is) during tripping time T.

## Block Diagram



## Characteristics

| **Settings** | |
|---|---|
| **Set Point Is** | |
| Setting range | 0.02 $I'_N$ to 2 $I'_N$ with a minimum value of 0.05 A |
| Accuracy [1] | ±5% |
| Resolution | 0.01 A |
| Drop out/pick up ratio | 93.5% |
| **Time Delay** | |
| Setting range | 0.1 to 300 s |
| Accuracy [1] | ±2% or ±25 ms |
| Resolution | 10 ms or 1 digit |
| **Characteristic Times [1]** | |
| Operation time | Pick-up < 35 ms |
| Overshoot time | < 35 ms |
| Reset time | < 50 ms |

| **Inputs** | | | |
|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** |
| Protection reset | P51C_x_101 | ■ | ■ |
| Protection blocking | P51C_x_113 | ■ | ■ |

| **Outputs** | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output | P51C_x_1 | ■ | ■ | |
| Tripping output | P51C_x_3 | ■ | ■ | ■ |
| Protection blocked | P51C_x_16 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

# Overvoltage (L-L or L-N)
## ANSI Code 59

*Protection against phase-to-neutral or phase-to-phase overvoltages.*

## Description

Protection against overvoltages or checking for sufficient voltage to enable source transfer.

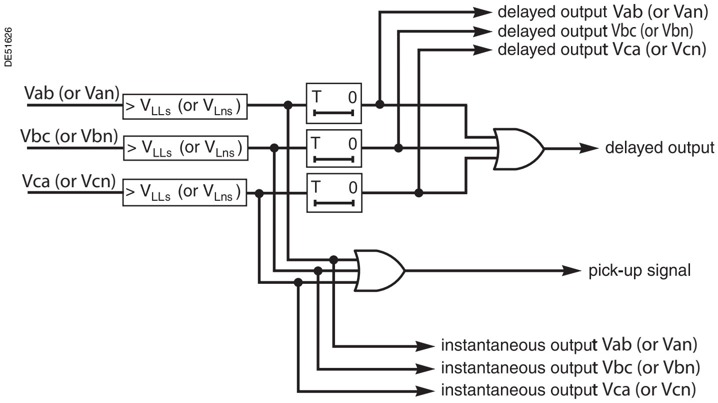
- the protection function is single-phase and operates with phase-to-neutral or phase-to-phase voltage
- it includes a definite time delay, T
- in phase-to-neutral operation, it indicates the faulty phase in the alarm associated with the fault

Operation with phase-to-neutral or phase-to-phase voltage depends on the connection selected for the voltage inputs.

| **Connection conditions** | | | | | |
|---|---|---|---|---|---|
| Type of connection | Van, Vbn, Vcn [1] | Vab, Vbc + Vr | Vab, Vbc | Vab [1] | Van [1] |
| Phase-to-neutral operation | YES | YES | NO | NO | On Van only |
| Phase-to-phase operation | YES | YES | YES | On Vab only | NO |

***(1)** With or without Vr.*

## Block Diagram


DE51626
Vab (or Van)
Vbc (or Vbn)
Vca (or Vcn)
> $V_{LLs}$ (or $V_{Lns}$)
> $V_{LLs}$ (or $V_{Lns}$)
> $V_{LLs}$ (or $V_{Lns}$)
T 0
T 0
T 0
delayed output Vab (or Van)
delayed output Vbc (or Vbn)
delayed output Vca (or Vcn)
delayed output
pick-up signal
instantaneous output Vab (or Van)
instantaneous output Vbc (or Vbn)
instantaneous output Vca (or Vcn)

## Characteristics

| **Settings** | |
|---|---|
| **Measurement Origin** | |
| Setting range | Main channels ($V_{LL}$) / Additional channels ($V_{LL}$') |
| **Voltage Mode** | |
| Setting range | Phase-to-phase voltage / Phase-to-neutral voltage |
| **$V_{LL}$s (or $V_{Ln}$s) Set Point** | |
| Setting range | 50% of $V_{LL}$p (or $V_{Ln}$p) to 150% of $V_{LL}$p (or $V_{Ln}$p) |
| Accuracy [1] | ±2% |
| Resolution | 1% |
| Drop out/pick up ratio | 97% ±1% |
| **Time Delay T** | |
| Setting range | 50 ms to 300 s |
| Accuracy [1] | ±2% or ±25 ms |
| Resolution | 10 ms or 1 digit |
| **Characteristic Times** | |
| Operation time | Pick-up < 40 ms from 0.9 $V_{LL}$s ($V_{Ln}$s) to 1.1 $V_{LL}$s ($V_{Ln}$s) (typically 25 ms) |
| Overshoot time | < 40 ms from 0.9 $V_{LL}$s ($V_{Ln}$s) to 1.1 $V_{LL}$s ($V_{Ln}$s) |
| Reset time | < 50 ms from 1.1 $V_{LL}$s ($V_{Ln}$s) to 0.9 $V_{LL}$s ($V_{Ln}$s) |

| **Inputs** | | | |
|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** |
| Protection reset | P59_x_101 | ■ | ■ |
| Protection blocking | P59_x_113 | ■ | ■ |

| **Outputs** | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P59_x_1 | ■ | ■ | |
| Delayed output | P59_x_3 | ■ | ■ | ■ |
| Fault phase a [2] | P59_x_7 | ■ | ■ | |
| Fault phase b[2] | P59_x_8 | ■ | ■ | |
| Fault phase c[2] | P59_x_9 | ■ | ■ | |
| Protection blocked | P59_x_16 | ■ | ■ | |
| Instantaneous output Van or Vab | P59_x_23 | ■ | ■ | |
| Instantaneous output Vbn or Vbc | P59_x_24 | ■ | ■ | |
| Instantaneous output Vcn or Vca | P59_x_25 | ■ | ■ | |
| Delayed output Van or Vab | P59_x_26 | ■ | ■ | |
| Delayed output Vbn or Vbc | P59_x_27 | ■ | ■ | |
| Delayed output Vcn or Vca | P59_x_28 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

***(2)**When the protection function is used for phase-to-neutral voltage.*

# Neutral Voltage Displacement
ANSI Code 59N

*Protection against insulation faults*

## Description

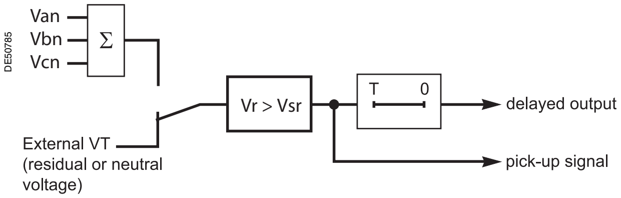
This function provides protection against insulation faults by measuring the residual voltage Vr or the neutral point voltage $V_{Ln}t$ for generators and motors.

The residual voltage is obtained by the vector sum of the phase voltages or by measurements using delta connected VTs. The neutral point voltage is measured by a VT inserted in the neutral point of the generator or the motor.

The protection function includes a time delay T, either definite or IDMT (dependent on the residual voltage Vr) (see tripping curve equation on page 173).

It operates only when a residual or neutral point voltage is available, by connecting VanVbnVcn, Vr, or $V_{Ln}t$.

## Block Diagram



## Characteristics

| **Settings** | |
|---|---|
| **Measurement Origin** | |
| Setting range | Main channels (Vr)<br>Additional channels (V'r)<br>Neutral-point voltage ($V_{Ln}t$) |
| **Tripping Curve** | |
| Setting range | Definite time<br>IDMT (dependent on the residual voltage Vr) |
| **Vsr Set Point** | |
| Definite time setting range | 2% to 80% $V_{LL}p$ (for residual voltage Vr)<br>2% to 80% Vntp (for neutral point voltage Vnt) |
| IDMT setting range | 2% to 10 % $V_{LL}p$ (for residual voltage Vr)<br>2% to 10 % Vntp (for neutral point voltage $V_{Ln}t$) |
| Accuracy (1) | ±2% or 0.005 $V_{LL}p$ |
| Resolution | 1% |
| Drop out/pick up ratio | 97% ±2% or > (1 - 0.006 $V_{LL}p$/Vsr) x 100% |
| **Time Delay T (Tripping Time at 2 Vsr)** | |
| Definite time setting range | 50 ms to 300 s |
| IDMT setting range | 100 ms to 10 s |
| Accuracy (1) | ±2% or ±25 ms |
| Resolution | 10 ms or 1 digit |
| **Characteristic Times** | |
| Operation time | pick-up < 45 ms (typically 25 ms) at 2 Vsr |
| Overshoot time | < 40 ms at 2 Vsr |
| Reset time | < 40 ms at 2 Vsr |

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Protection reset | P59N_x_101 | ■ | ■ |
| Protection blocking | P59N_x_113 | ■ | ■ |

**Outputs**

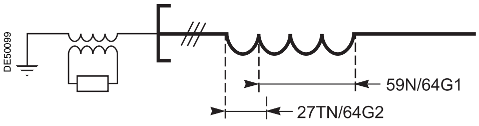
| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Instantaneous output (pick-up) | P59N_x_1 | ■ | ■ | |
| Delayed output | P59N_x_3 | ■ | ■ | ■ |
| Protection blocked | P59N_x_16 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

# 100% Stator Ground Fault
## ANSI Code 64G

*Protection against internal faults in generators.*



### Description

The 64G protection function is made of the two independent functions.

- protection function 64G1 which commonly corresponds to a neutral voltage displacement function at the fundamental frequency (ANSI code 59N). It may be implemented by a ground fault protection function (ANSI code 51N) when the ground fault current is sufficient.
- protection function 64G2 which corresponds to a third harmonic undervoltage function (ANSI code 27TN) whose operating principle depends on the type of connection of the generator terminal VTs.

When a single-phase fault occurs, the flow of the zero sequence current increases the potential of the neutral point, detected by protection function 59N. However, given the natural unbalance of the three network phases, the sensitivity set point for 59N cannot be set under 10% to 15% of the phase-to-neutral voltage.

If the single-phase fault occurs on a stator winding near the neutral point, the increase in the potential at the neutral point may be insufficient to trip protection function 59N.

The combination of functions 59N and 27TN is the means to protect 100% of the stator winding. Depending on the settings:

- protection function 59N protects 85 to 95% of the stator winding on the terminal side and
- protection function 27TN protects 10 to 20% of the stator winding on the neutral point side.

To create a 100% stator ground fault protection function, it is necessary to implement the 64G1 (59N or 51N) and the 64G2 (27TN) protection functions (see each of these functions for more information).

# Restricted Ground Fault Differential
## ANSI Code 64REF

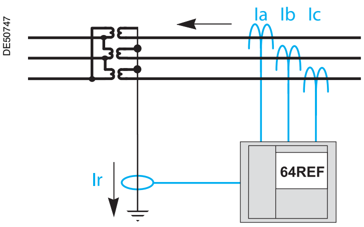
*Protection of 3-phase windings against phase-to-ground faults.*

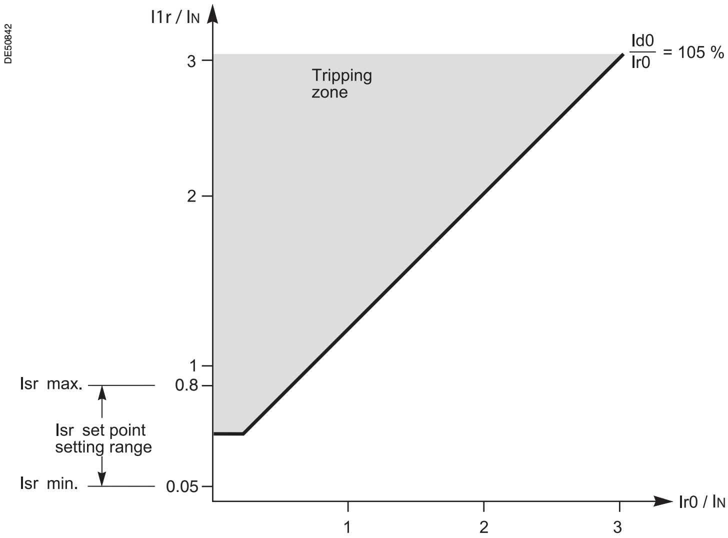
## Description

The restricted ground fault protection function detects phase-to-ground faults on three-phase windings with grounded neutral. This function protects generators and transformers.

The protected zone, depending on the measurement origin and the set parameters, is between:

- the Ia, Ib, Ic CTs and the neutral point current measurement Ir
- the I'a, I'b, I'c CTs and the neutral point current measurement I'r.





The function is based on the comparison of the residual current calculated using the sum of the three phase currents and the neutral point current. These two currents define the differential residual current and the restrained current:

- differential residual current: $I1r = \left|\vec{I}r\Sigma - \vec{I}r\right|$
- restrained current or through residual current: the value of the restrained current depends on detection of a fault outside the protected zone:
  - ☐ without detection of an external fault

    $$Ir0 = \left|\vec{I}r\Sigma\right|$$

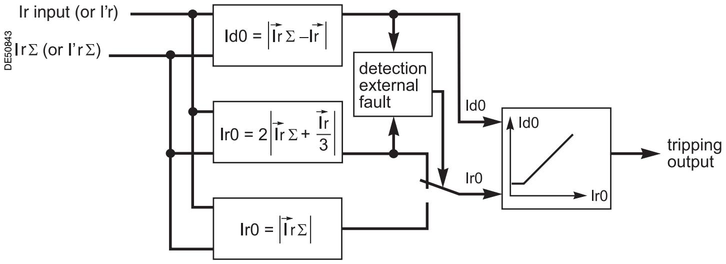
  - ☐ with detection of an external fault: the protection function is insensitive to saturation of the CTs, but its operation is not blocked.

    $$Ir0 = 2 \times \left|\vec{I}r\Sigma + \frac{\vec{I}r}{3}\right|$$

The function picks up if the differential residual current is greater than the operating set point. The set point is defined by:

- the minimum set point Is0
- a tripping characteristic with a slope of 1.05 (differential residual current vs. restrained current).

## Block Diagram



# Restricted Ground Fault Differential
ANSI Code 64REF

## Sizing Current Transformers

The primary currents of the current transformers used must comply with the following rule:
**$0.1\, I_N \leq I_{Nr} \leq 2\, I_N$**
with $I_N$ = primary current of phase CTs
and $I_{Nr}$ = primary current of the neutral point CT.

The current transformer should be defined by which equation produces the highest knee point voltage:

a. $V_k \geq (R_{CT} + R_w) \times 20\, I_N$
b. $V_k \geq (R_{CT} + R_w)\, (1.6\, I_{3P} / I_N) \times I_N$
c. $V_k \geq (R_{CT} + R_w)\, (2.4\, I_{1P} / I_N) \times I_N$

The equations apply to the phase current transformers and the neutral-point current transformer.
**$I_N$** is the CT rated secondary current.
**$R_{CT}$** is the CT internal resistance.
**$R_w$** is the resistance of the CT load and wiring.
**$I_{3P}$** is the maximum current value for a three-phase short-circuit.
**$I_{1P}$** is the maximum current value for a phase-to-ground short-circuit.

## Characteristics

| | | | | |
|---|---|---|---|---|
| **Settings** | | | | |
| **Measurement Origin** | | | | |
| Setting range | Main channels (I, Ir)<br>Additional channels (I', I'r) | | | |
| **Isr** | | | | |
| Setting range | $0.05\, I_N$ to $0.8\, I_N$ for $I_N \geq 20$ A<br>$0.1\, I_N$ to $0.8\, I_N$ for $I_n < 20$ A | | | |
| Accuracy (1) | 5% | | | |
| Resolution | 1 A or 1 digit | | | |
| Drop out/pick up ratio | 93% ±2% | | | |
| **Characteristic Times** | | | | |
| Operation time | < 55 ms at $I_{1r} = 2.1\, I_{r0}$ | | | |
| Overshoot time | < 35 ms at $I_{1r} = 2.1\, I_{r0}$ | | | |
| Reset time | < 45 ms at $I_{1r} = 2.1\, I_{r0}$ | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P64REF_x_101 | ■ | ■ | |
| Protection blocking | P64REF_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Protection output | P64REF_x_3 | ■ | ■ | ■ |
| Protection blocked | P64REF_x_16 | ■ | ■ | |

*x: unit number.*
***(1)** Under reference conditions (IEC 60255-6).*

# Starts per Hour
ANSI Code 66

*Motor protection against heat rise caused overly frequent starts.*

## Description
Protection against motor overheating caused by:
- overly frequent starts: motor energizing is blocked when the maximum permissible number of starts is reached
- starts occur too close to one another: motor re-energizing after a shutdown is allowed only after an adjustable time delay.

Starting is detected when the current drawn rises above 5% of current IB.
The number of starts is limited by:
- the number of starts (Nt) allowed per period of time (P)
- the permissible number of consecutive hot starts (Nh)
- the permissible number of consecutive cold starts (Nc).

DE50844

The number of consecutive starts is the number starts counted during the last P/Nt minutes.

The motor hot state corresponds to the overshooting of the fixed set point (50% heat rise) of the thermal overload function. During re-acceleration, the motor is subjected to a stress similar to that of starting without the current first passing through a value less than 5% of IB. In this case, the number of starts is not incremented. It is however possible to increment the number of starts for a re-acceleration using a logic input or information from a logic equation or Logipam program ("motor re-acceleration" input).

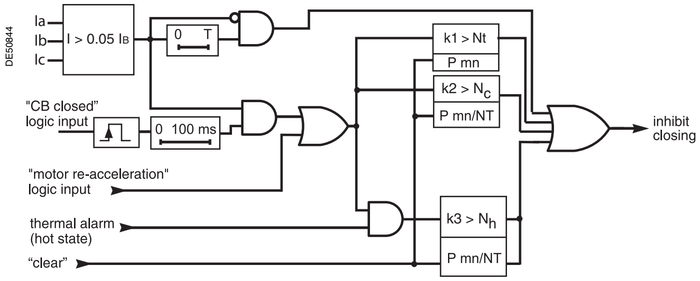
The "stop/start" time delay T may be used to block starting after a stop until the delay has elapsed and thus impose a minimum stop time before each restart.

**Use of Circuit Breaker Closed Data**
In synchronous motor applications, it is advisable to connect the "circuit breaker closed" data to a logic input in order to enable more precise detection of starts.

**User Information**
The following information is available for the user:
- the time before a start is allowed
- the number of starts still allowed.

See the section on machine diagnosis.

## Block Diagram



where **k1** = counter #1 for total starts
**k2** = counter #2 for cold starts
**Nc** = number of cold starts
**Nh** = number of hot starts
**Nt** = total number of starts allowed per period of time.
**k3** = counter #3 for hot starts
**P** = period of time

## Characteristics

| **Settings** | |
|---|---|
| **Period of Time (P)** | |
| Setting range | 1 to 6 hours |
| Resolution | 1 h |
| **Total Number of Starts (Nt) Allowed per Period of Time (P)** | |
| Setting range | 1 to 60 |
| Resolution | 1 |
| **Number of Consecutive Hot Starts (Nh)** | |
| Setting range | 1 to Nf |
| Resolution | 1 |
| **Number of Consecutive Cold Starts (Nc)** | |
| Setting range | 1 to Nt |
| Resolution | 1 |
| **Stop/start Time Delay** | |
| Setting range | 0 to 90 min. (0 = no delay) |
| Resolution | 1 min. |

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Protection reset | P66_1_101 | ■ | ■ |
| Motor re-acceleration | P66_1_102 | ■ | ■ |
| Protection blocking | P66_1_113 | ■ | ■ |

**Outputs**

| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Protection output | P66_1_3 | ■ | ■ | ■ |
| Protection blocked | P66_1_16 | ■ | ■ | |
| Stop/start block | P66_1_29 | ■ | ■ | |
| Total number starts reached | P66_1_30 | ■ | ■ | |
| Total consecutive starts reached | P66_1_31 | ■ | ■ | |

# Directional Phase Overcurrent
ANSI Code 67

*Phase-to-phase short-circuit protection, with selective tripping according to fault current direction.*

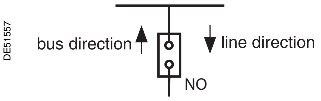
## Description

This function comprises a phase overcurrent function associated with direction detection and picks up if the phase overcurrent function in the chosen direction (line or bus) is activated for at least one of the three phases (or two of the three, depending on the settings).

- the protection function is 3-phase and has a definite or IDMT time delay.
- each of the two units has two groups of settings. Switching to setting group A or B can be carried out by a logic input or remote control command, depending on the settings.
- the customized curve, defined point by point, may be used with this protection function.
- an adjustable timer hold, definite time or IDMT, can be used for coordination with electromagnetic relays and to detect restriking faults.
- the alarm linked to the protection function indicates the faulty phase or phases.

**Tripping Direction**

Current flow direction is determined by measuring the phase in relation to a polarization value. It is qualified as either bus or line direction, as shown below:


DE51557
bus direction
line direction
NO

Tripping can be set to occur in either zone. The zone in which tripping does not occur is used for indication.

**Polarization Value**

The polarization value is the phase-to-phase value in quadrature with the current for $\cos\theta = 1$ (90° connection angle). A phase current vector plane is divided into two half-planes that correspond to the line zone and bus zone. The characteristic angle θ is the angle of the perpendicular to the boundary line between the two zones and the polarization value.

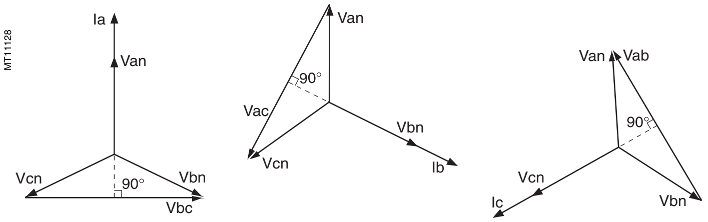
**Voltage Memory**

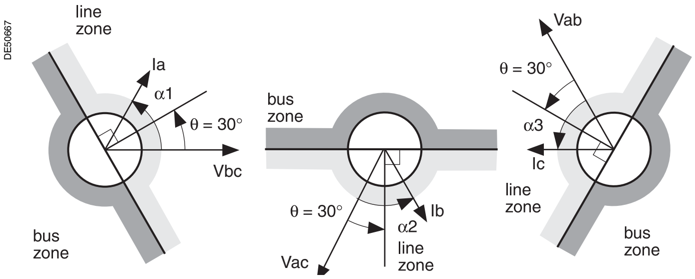
Should all the voltages disappear during a 3-phase fault near the bus, the voltage level may be insufficient for the fault direction to be detected (< 1.5 % $V_{LLp}$). The protection function therefore uses a voltage memory to reliably determine the direction. The fault direction is saved as long as the voltage level is too low and the current is above the Is set point.

**Closing on a Pre-Existing Fault**

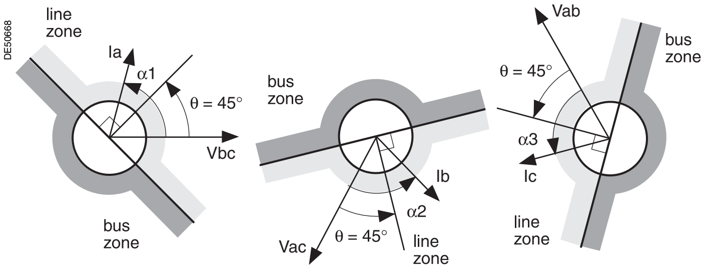
If the circuit breaker is closed when there is a pre-existing 3-phase fault on the bus, the voltage memory is blank. As a result, the direction cannot be determined and the protection does not trip.

In such cases, a backup 50/51 protection function should be used.

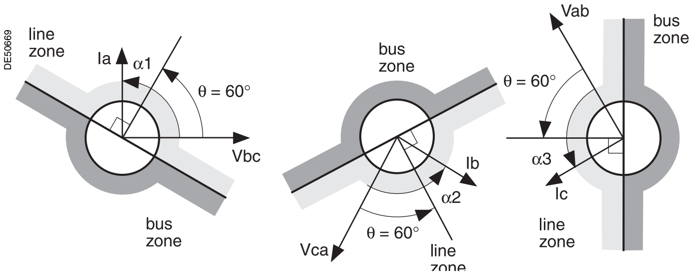

MT11128
Ia
Van
Vcn
90°
Vbn
Vbc
Van
90°
Vac
Vbn
Vcn
Ib
Van
Vab
90°
Vcn
Ic
Vbn


DE50667
line zone
Ia
α1
θ = 30°
Vbc
bus zone
bus zone
θ = 30°
α2
Ib
Vac
line zone
Vab
θ = 30°
α3
Ic
line zone
bus zone

*Fault tripping in line zone with θ = 30°*


DE50668
line zone
Ia
α1
θ = 45°
Vbc
bus zone
bus zone
Ib
α2
θ = 45°
Vac
line zone
Vab
bus zone
θ = 45°
α3
Ic
line zone

*Fault tripping in line zone with θ = 45°*


DE50669
line zone
Ia
α1
θ = 60°
Vbc
bus zone
bus zone
Ib
α2
θ = 60°
Vca
line zone
Vab
bus zone
θ = 60°
α3
Ic
line zone

*Fault tripping in line zone with θ = 60°*

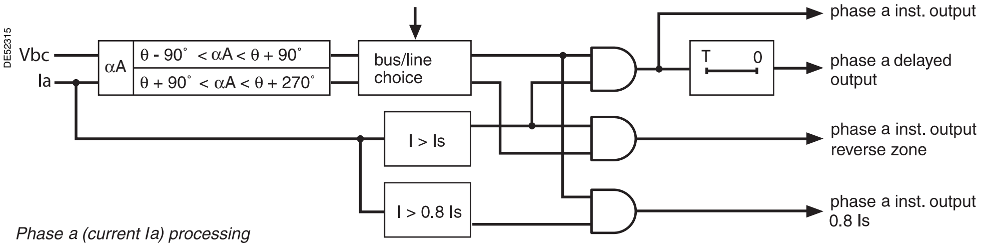
**Tripping Logic**

In certain cases, it is wise to select the "two out of three phases" tripping logic. Such cases may occur when two parallel transformers (Dy) must be protected. For a 2-phase fault on a transformer primary winding, there is a 2-1-1 current distribution at the secondary end. The highest current is in the expected zone (operation zone for the faulty main, no operation zone for the fault-free main).

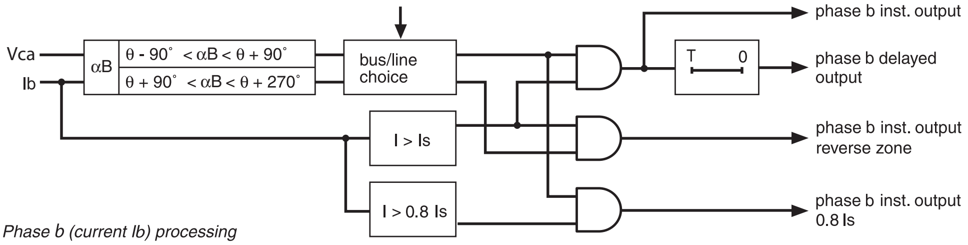
One of the lowest currents is at the edge of the zone. According to the line parameters, it may even be in the wrong zone. There is therefore a risk of tripping both mains.

# Directional Phase Overcurrent
## ANSI Code 67

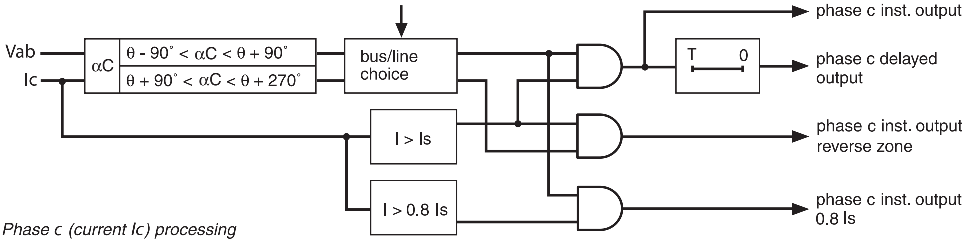
### Block Diagram


DE52315
Vbc
Ia
αA
θ - 90˚ < αA < θ + 90˚
θ + 90˚ < αA < θ + 270˚
bus/line choice
I > Is
I > 0.8 Is
T 0
phase a inst. output
phase a delayed output
phase a inst. output reverse zone
phase a inst. output 0.8 Is

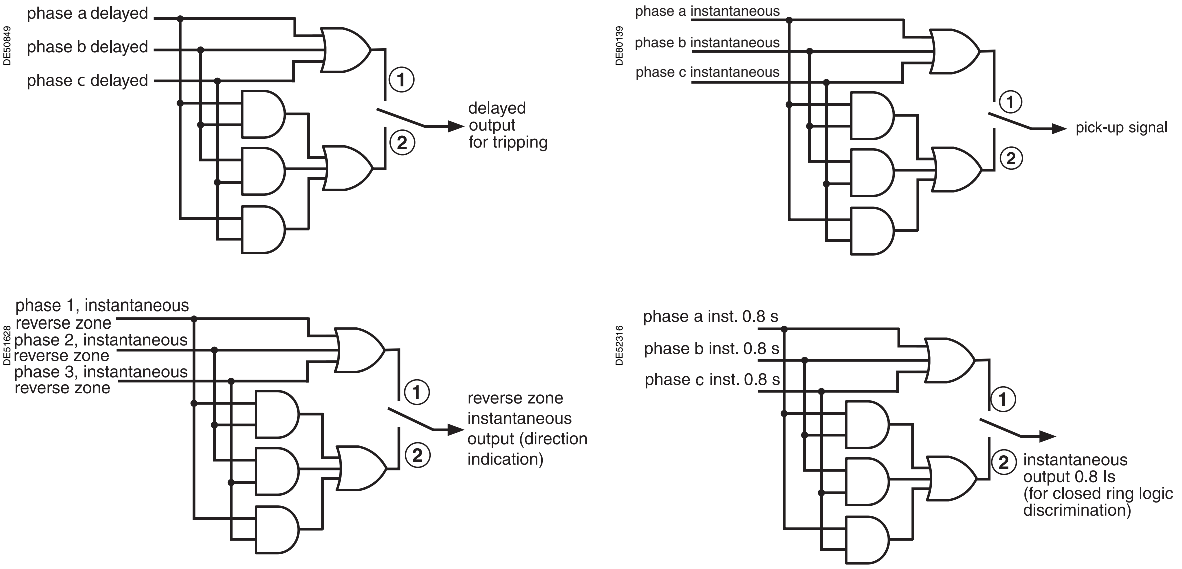
*Phase a (current Ia) processing*


Vca
Ib
αB
θ - 90˚ < αB < θ + 90˚
θ + 90˚ < αB < θ + 270˚
bus/line choice
I > Is
I > 0.8 Is
T 0
phase b inst. output
phase b delayed output
phase b inst. output reverse zone
phase b inst. output 0.8 Is

*Phase b (current Ib) processing*


Vab
Ic
αC
θ - 90˚ < αC < θ + 90˚
θ + 90˚ < αC < θ + 270˚
bus/line choice
I > Is
I > 0.8 Is
T 0
phase c inst. output
phase c delayed output
phase c inst. output reverse zone
phase c inst. output 0.8 Is

*Phase c (current Ic) processing*


DE50849
phase a delayed
phase b delayed
phase c delayed
1
2
delayed output for tripping
DE80139
phase a instantaneous
phase b instantaneous
phase c instantaneous
1
2
pick-up signal
DE51628
phase 1, instantaneous reverse zone
phase 2, instantaneous reverse zone
phase 3, instantaneous reverse zone
1
2
reverse zone instantaneous output (direction indication)
DE52316
phase a inst. 0.8 s
phase b inst. 0.8 s
phase c inst. 0.8 s
1
2
instantaneous output 0.8 Is (for closed ring logic discrimination)

*Grouping output data.*

*Tripping logic parameter setting:*

① *one out of three*

② *two out of three*

| Tripping Curve | TimerHhold |
|---|---|
| Definite time (DT) | Definite time |
| Standard inverse time (SIT) | Definite time |
| Very inverse time (VIT or LTI) | Definite time |
| Extremely inverse time (EIT) | Definite time |
| Ultra inverse time (UIT) | Definite time |
| RI curve | Definite time |
| IEC inverse time SIT / A | Definite time or IDMT |
| IEC very inverse time VIT or LTI / B | Definite time or IDMT |
| IEC extremely inverse time EIT / C | Definite time or IDMT |
| IEEE moderately inverse (IEC / D) | Definite time or IDMT |
| IEEE very inverse (IEC / E) | Definite time or IDMT |
| IEEE extremely inverse (IEC / F) | Definite time or IDMT |
| IAC inverse | Definite time or IDMT |
| IAC very inverse | Definite time or IDMT |
| IAC extremely inverse | Definite time or IDMT |
| Customized | Definite time |

## Characteristics

| | | |
|---|---|---|
| **Settings** | | |
| **Characteristic Angle $\theta$** | | |
| Setting range | | 30°, 45°, 60° |
| Accuracy (1) | | ±2% |
| **Tripping Curve** | | |
| Setting range | | See list above |
| **Is Set Point** | | |
| Setting range | definite time | 0.1 IN ≤ Is ≤ 24 IN in amperes |
| | IDMT | 0.1 IN ≤ Is ≤ 2.4 IN in amperes |
| Accuracy (1) | | ±5% or ±0.01 IN |
| Resolution | | 1 A or 1 digit |
| Drop out/pick up ratio | | 93.5% ±5% or > (1 - 0.015 IN/Is) x 100% |
| **Time Delay T (Operation Time at 10 Is)** | | |
| Setting range | definite time | Inst, 50 ms ≤ T ≤ 300 s |
| | IDMT | 100 ms ≤ T ≤ 12.5 s or TMS (2) |
| Accuracy (1) | definite time (4) | ±2% or from –10 ms to +25 ms |
| | IDMT | Class 5 or from –10 ms to +25 ms |
| Resolution | | 10 ms or 1 digit |
| **Advanced Settings** | | |
| **Tripping Direction** | | |
| Setting range | | Bus / line |
| **Tripping Logic** | | |
| Setting range | | One out of three / two out of three |
| **Timer Hold T1** | | |
| Setting range | definite time | 0; 0.05 to 300 s |
| | IDMT (3) | 0.5 to 20 s |
| Resolution | | 10 ms or 1 digit |
| **Characteristic Times** | | |
| Operation time | | pick-up < 75 ms at 2 Is (typically 65 ms)<br>Inst. < 90 ms at 2 Is (confirmed instantaneous) (typically 75 ms) |
| Overshoot time | | < 45 ms at 2 Is |
| Reset time | | < 55 ms at 2 Is (for T1 = 0) |

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Protection reset | P67_x_101 | ■ | ■ |
| Protection blocking | P67_x_113 | ■ | ■ |

**Outputs**

| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Instantaneous output (pick-up) | P67_x_1 | ■ | ■ | |
| Delayed output | P67_x_3 | ■ | ■ | ■ |
| Drop out | P67_x_4 | ■ | ■ | |
| Instantaneous output (reverse zone) | P67_x_6 | ■ | ■ | |
| Phase a fault | P67_x_7 | ■ | ■ | |
| Phase b fault | P67_x_8 | ■ | ■ | |
| Phase c fault | P67_x_9 | ■ | ■ | |
| Protection blocked | P67_x_16 | ■ | ■ | |
| Instantaneous output at 0.8 Is | P67_x_21 | ■ | ■ | |
| 1 out of 3 delayed output | P67_x_36 | ■ | ■ | |
| 2 out of 3 delayed output | P67_x_37 | ■ | ■ | |

*x: unit number.*

*(1) Under reference conditions (IEC 60255-6).*

*(2) Setting ranges in TMS (Time Multiplier Setting) mode*
*Inverse (SIT) and IEC SIT/A: 0.04 to 4.20*
*Very inverse (VIT) and IEC VIT/B: 0.07 to 8.33*
*Very inverse (LTI) and IEC LTI/B: 0.01 to 0.93*
*Ext. inverse (EIT) and IEC EIT/C: 0.13 to 15.47*
*IEEE moderately inverse: 0.42 to 51.86*
*IEEE very inverse: 0.73 to 90.57*
*IEEE extremely inverse: 1.24 to 154.32*
*IAC inverse: 0.34 to 42.08*
*IAC very inverse: 0.61 to 75.75*
*IAC extremely inverse: 1.08 to 134.4.*

*(3) Only for standardized tripping curves of the IEC, IEEE and IAC types.*

# Directional Ground Fault - Type 1

## ANSI Code 67N/67NC

*Ground fault protection, with selective tripping according to fault current direction.*

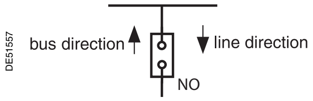
### Description

In order to adapt to all types of applications and all grounding systems, the protection function operates according to three different types of characteristics:

- **type 1:** the protection function uses Ir vector projection. This projection method is suitable for radial feeders in resistive, effectively ungrounded, or compensated neutral systems (designed to compensate for system capacitance using a tuned inductor in the neutral. This is not common in North America).
- **type 2:** the protection function uses the Ir vector magnitude and operates like a ground fault protection function with an added direction criterion. This projection method is used with closed ring distribution networks with directly grounded neutral.
- **type 3:** the protection function uses the Ir vector magnitude and complies with Italian specification ENEL DK5600. It operates like a ground fault protection function with an added angular direction criterion {*Lim.1*, *Lim.2*}. This protection method is suitable for distribution networks in which the neutral grounding system varies according to the operational mode.

**Tripping direction**

The direction of the residual current is qualified as bus direction or line direction according to the following convention:

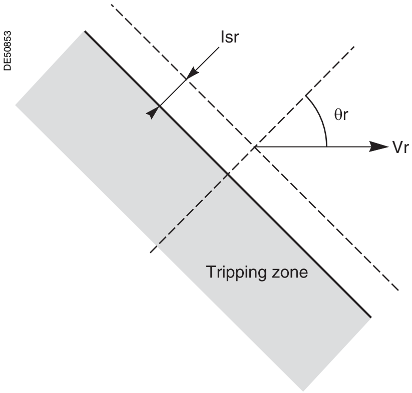


The tripping zone is set for tripping in the bus zone or in the line zone.

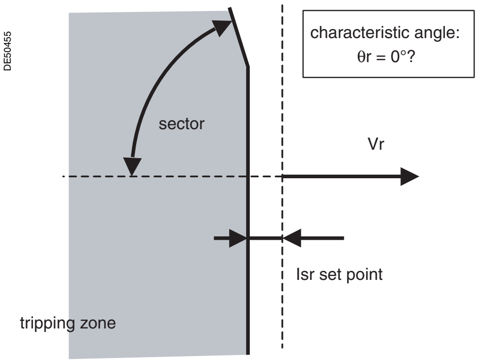
The reverse zone is the zone for which the protection function does not trip. The detection of current in the reverse zone is used for indication.

# Directional Ground Fault - Type 1
## ANSI Code 67N/67NC

*Ground fault protection for impedant or compensated neutral systems.*


DE50853
Isr
θr
Vr
Tripping zone

*Tripping characteristic of ANSI 67N/67NC type 1 protection (characteristic angle θ0 ≠ 0°).*


DE50455
characteristic angle:
θr = 0°?
sector
Vr
Isr set point
tripping zone

*Tripping characteristic of ANSI 67N/67NC type 1 protection (characteristic angle θ0 = 0°).*

### Description

The function determines the projection of the residual current Ir on the characteristic line, the position of which is determined by the setting of characteristic angle θr in relation to the residual voltage. The projection value is compared to the Isr set point. This protection function is suitable for radial feeders in resistive, effectively ungrounded or compensated neutral systems (designed to compensate for system capacitance using a tuned inductor in the neutral. This is not common in North America).

With compensated neutral systems, it is characterized by its capacity to detect very brief, repetitive faults (recurrent faults). In the case of Petersen coils with no additional resistance, fault detection under steady state conditions is not possible due to the absence of active zero sequence current. The protection function uses the transient current at the beginning of the fault to ensure tripping.

The θr = 0° setting is suitable for compensated or resistance grounded systems. When this setting is selected, the parameter setting of the sector is used to reduce the protection tripping zone to ensure its stability on fault-free feeders.

The protection function operates with the residual current measured at one of the relay Ir inputs (operation with sum of three currents impossible). The protection function is blocked for residual voltages below the Vsr set point.

It implements a definite time (DT) delay.

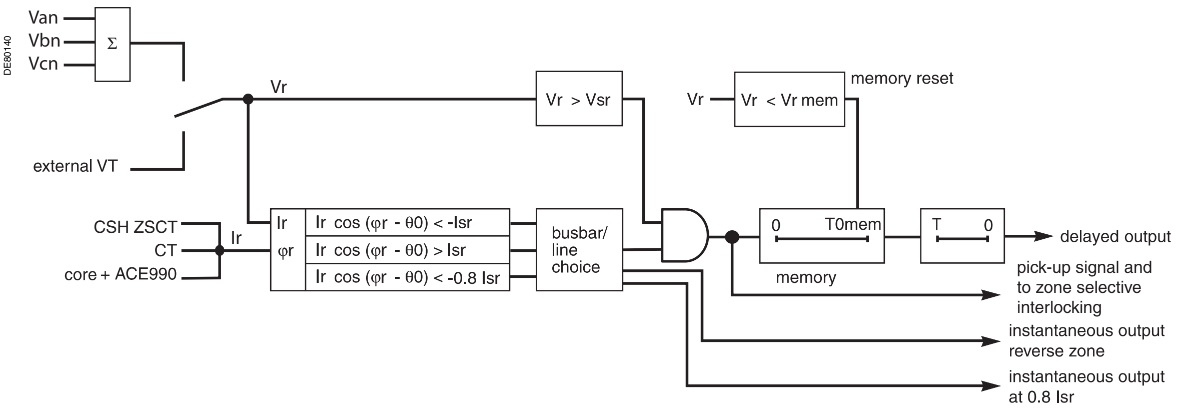
The tripping direction may be set at the bus end or line end.

Each of the two units has two groups of settings. Switching to setting group A or B can be carried out by a logic input or a remote control command, depending on the settings.

**Memory**

The detection of recurrent faults is controlled by the time delay T0mem which extends the transient pick-up information, thereby enabling the operation of the definite time delay even with faults that are rapidly extinguished (≈ 2 ms) and restrike periodically. Even when a Petersen coil with no additional resistance is used, tripping is ensured due to fault detection during the transient fault appearance. Detection is extended throughout the duration of the fault based on the criterion Vr ≥ Vr mem, within the limit of T0mem. With this type of application, T0mem must be greater than T (definite time delay).

### Block Diagram


DE80140
Van
Vbn
Vcn
Σ
Vr
external VT
Vr > Vsr
Vr
Vr < Vr mem
memory reset
CSH ZSCT
CT
core + ACE990
Ir
Ir
φr
Ir cos (φr - θ0) < -Isr
Ir cos (φr - θ0) > Isr
Ir cos (φr - θ0) < -0.8 Isr
busbar/
line
choice
0
T0mem
memory
T
0
delayed output
pick-up signal and
to zone selective
interlocking
instantaneous output
reverse zone
instantaneous output
at 0.8 Isr

# Directional Ground Fault - Type 1
ANSI Code 67N/67NC

## Characteristics

| | | | |
|---|---|---|---|
| **Settings** | | | |
| **Measurement Origin** | | | |
| Setting range | | | Ir / I'r |
| **Characteristic Angle θ** | | | |
| Setting range | | | -45°, 0°, 15°, 30°, 45°, 60°, 90° |
| Accuracy (1) | | | ±2° |
| **Isr Setting** | | | |
| Setting range | | | 0.01 INr ≤ Isr ≤ 15 INr (min. 0.1 A) in amperes |
| | Sum of CTs | | 0.01 IN ≤ Isr ≤ 15 In (min. 0.1 A) |
| | With CSH sensor | 2 A rating | 0.1 to 30 A |
| | | 20 A rating | 0.2 to 300 A |
| | CT | | 0.01 INr ≤ Isr ≤ 15 INr (min. 0.1 A) |
| | Zero sequence CT with ACE990 | | 0.01 INr ≤ Isr ≤ 15 INr (min. 0.1 A) |
| Accuracy (1) | | | ±5% (at φr = 180°) |
| Resolution | | | 1 A or 1 digit |
| Drop out/pick up ratio | | | 93.5% ±5% |
| **Time Delay T (Definite Time (DT) Tripping Curve)** | | | |
| Setting range | | | Inst, 50 ms ≤ T ≤ 300 s |
| Accuracy (1) | | | ±2% or from -10 ms to +25 ms |
| Resolution | | | 10 ms or 1 digit |
| **Advanced Settings** | | | |
| **Tripping Direction** | | | |
| Setting range | | | Bus / line |
| **Vsr Set Point** | | | |
| Setting range | | | 2% to 80% $V_{LL}$p |
| Accuracy (1) | | | ±5% or ±0.005 $V_{LL}$p |
| Resolution | | | 1% |
| Drop out/pick up ratio | | | 93.5% ±5%<br>or > (1 - 0.006 $V_{LL}$p/Vsr) x 100% |
| **Sector** | | | |
| Setting range | | | 86°, 83°, 76° |
| Accuracy (1) | | | ±2° |
| **Memory Time Tr mem** | | | |
| Setting range | | | 0; 0.05 to 300 s |
| Resolution | | | 10 ms or 1 digit |
| **Memory Voltage Vr mem** | | | |
| Setting range | | | 0; 2 to 80% of $V_{LL}$p |
| Resolution | | | 1% |
| **Characteristic Times** | | | |
| Operation time | | | Pick-up < 55 ms at 2 Isr |
| Overshoot time | | | < 45 ms at 2 Isr |
| Reset time | | | < 50 ms (at Tr mem = 0) |

**Inputs**

| **Designation** | **Syntax** | **Equations** | **Logipam** |
|---|---|---|---|
| Protection reset | P67N_x_101 | ■ | ■ |
| Protection blocking | P67N_x_113 | ■ | ■ |

**Outputs**

| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
|---|---|---|---|---|
| Instantaneous output (pick-up) | P67N_x_1 | ■ | ■ | |
| Delayed output | P67N_x_3 | ■ | ■ | ■ |
| Drop-out | P67N_x_4 | ■ | ■ | |
| Instantaneous output (reverse zone) | P67N_x_6 | ■ | ■ | |
| Protection blocked | P67N_x_16 | ■ | ■ | |
| Instantaneous output at 0.8 Isr | P67N_x_21 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6).*

## Standard Setting

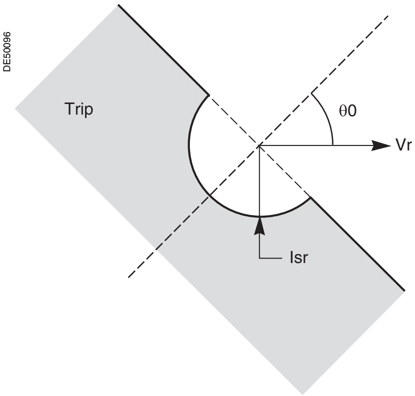
The settings below are given for usual applications in different grounding systems. The shaded boxes represent default settings.

| | **Isolated neutral** | **Impedant neutral** | **Compensated neutral** |
|---|---|---|---|
| Isr setting | Set according to coordination study | Set according to coordination study | Set according to coordination study |
| Characteristic angle θ0 | 90° | 0° | 0° |
| Time delay T | Set according to coordination study | Set according to coordination study | Set according to coordination study |
| Direction | Line | Line | Line |
| Vsr set point | 2% of $V_{LL}$s | 2% of $V_{LL}$s | 2% of $V_{LL}$s |
| Sector | N/A | 86° | 86° |
| Memory time T0mem | 0 | 0 | 200 ms |
| Memory voltage V0mem | 0 | 0 | 0 |

Schneider Electric

# Directional Ground Fault - Type 2
ANSI Code 67N/67NC

*Ground fault protection for impedant or solidly grounded systems.*


DE50096
Trip
θ0
Vr
Isr

*Tripping characteristic of ANSI 67N/67NC - type 2 protection function.*

## Description

The protection function operates like a ground fault protection function with an added direction criterion. It is suitable for closed ring distribution networks with solidly grounded neutral. It has all the characteristics of a ground fault protection function (50N/51N) and can therefore be easily coordinated with that function.

Residual current is the current measured at one of the Sepam™ Ir inputs or calculated using the sum of the main phase currents (I), according to the parameter setting.

The tripping direction may be set at the bus end or line end.

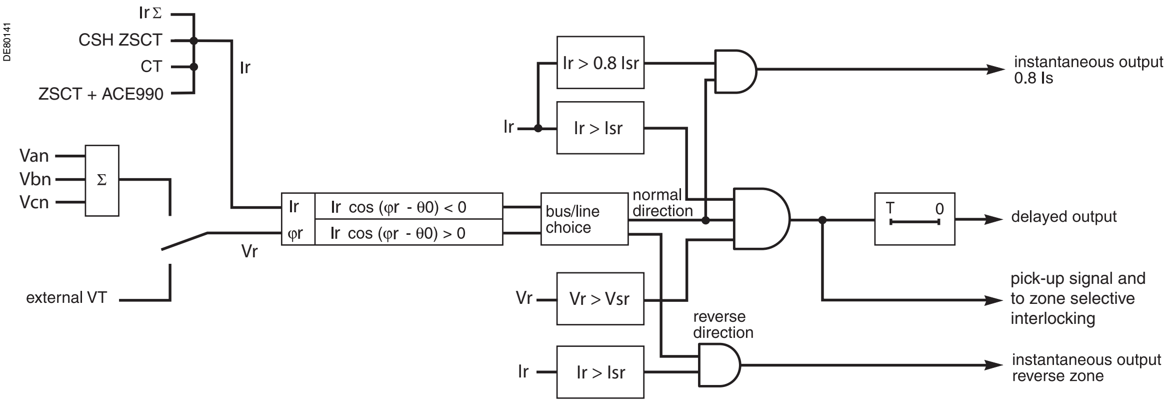
The protection function has a definite or IDMT time delay.

Each unit has two groups of settings. Switching to setting group A or B is carried out by a logic input or a remote control command, depending on the settings.

The customized curve, defined point by point, may be used with this protection function. An adjustable timer hold, definite time or IDMT, can be used for coordination with electromagnetic relays and to detect restriking faults.

| Tripping Curve | Timer Hold |
|---|---|
| Definite time (DT) | Definite time |
| Standard inverse time (SIT) | Definite time |
| Very inverse time (VIT or LTI) | Definite time |
| Extremely inverse time (EIT) | Definite time |
| Ultra inverse time (UIT) | Definite time |
| RI curve | Definite time |
| IEC inverse time SIT / A | Definite time or IDMT |
| IEC very inverse time VIT or LTI / B | Definite time or IDMT |
| IEC extremely inverse time EIT / C | Definite time or IDMT |
| IEEE moderately inverse (IEC / D) | Definite time or IDMT |
| IEEE very inverse (IEC / E) | Definite time or IDMT |
| IEEE extremely inverse (IEC / F) | Definite time or IDMT |
| IAC inverse | Definite time or IDMT |
| IAC very inverse | Definite time or IDMT |
| IAC extremely inverse | Definite time or IDMT |
| Customized | Definite time |

## Block Diagram


DE80141
IrΣ
CSH ZSCT
CT
ZSCT + ACE990
Ir
Van
Vbn
Vcn
Σ
Vr
external VT
Ir
φr
Ir cos (φr - θ0) < 0
Ir cos (φr - θ0) > 0
bus/line choice
normal direction
reverse direction
Ir
Ir > 0.8 Isr
Ir > Isr
Vr
Vr > Vsr
Ir
Ir > Isr
T 0
instantaneous output 0.8 Is
delayed output
pick-up signal and to zone selective interlocking
instantaneous output reverse zone

# Directional Ground Fault - Type 2
ANSI Code 67N/67NC

## Characteristics

| | | | |
|---|---|---|---|
| **Settings** | | | |
| **Measurement Origin** | | | |
| Setting range | | | Ir<br>I'r<br>IrΣ (sum of the main phase channels) |
| **Characteristic Angle θ** | | | |
| Setting range | | | -45°, 0°, 15°, 30°, 45°, 60°, 90° |
| Accuracy (1) | | | ±2° |
| **Tripping Curve** | | | |
| Setting range | | | See previous page |
| **Isr Setting** | | | |
| Definite time setting range | | | 0.01 INr ≤ Isr ≤ 15 INr (min. 0.1 A) in amperes |
| | Sum of CTs | | 0.01 IN ≤ Isr ≤ 15 IN (min. 0.1 A) |
| | With CSH sensor | 2 A rating | 0.1 to 30 A |
| | | 20 A rating | 0.2 to 300 A |
| | CT | | 0.01 INr ≤ Isr ≤ 15 INr (min. 0.1 A) |
| | Zero sequence CT with ACE990 | | 0.01 INr ≤ Isr ≤ 15 INr (min. 0.1 A) |
| IDMT setting range | | | 0.01 INr ≤ Isr ≤ INr (min. 0.1 A) in amperes |
| | Sum of CTs | | 0.01 IN ≤ Isr ≤ IN (min. 0.1 A) |
| | With CSH sensor | 2 A rating | 0.1 to 2 A |
| | | 20 A rating | 0.2 to 20 A |
| | CT | | 0.01 INr ≤ Isr ≤ INr (min. 0.1 A) |
| | Zero sequence CT with ACE990 | | 0.01 INr ≤ Isr ≤ INr (min. 0.1 A) |
| Accuracy (1) | | | ±5% or ±0.004 In0 |
| Resolution | | | 0.1 A or 1 digit |
| Drop out/pick up ratio | | | 93.5% ±5%<br>or > (1 - 0.005 INr/Isr) x 100% |
| **Time Delay T (Operation Time at 10 Isr)** | | | |
| Setting range | definite time | | Inst, 50 ms ≤ T ≤ 300 s |
| | IDMT | | 100 ms ≤ T ≤ 12.5 s or TMS (2) |
| Accuracy (1) | definite time | | ±2% or from -10 ms to +25 ms |
| | IDMT | | Class 5 or from -10 ms to +25 ms |
| Resolution | | | 10 ms or 1 digit |
| **Advanced Settings** | | | |
| **Tripping Direction** | | | |
| Setting range | | | Bus / line |
| **Vsr Set Point** | | | |
| Setting range | | | 2% to 80% $V_{LL}$p |
| Accuracy (1) | | | ±5% or ±0.005 $V_{LL}$p |
| Resolution | | | 1% |
| Drop out/pick up ratio | | | 93% ±5%<br>or > (1 - 0.006 $V_{LL}$p/Vsr) x 100% |
| **Timer Hold T1** | | | |
| Setting range | definite time | | 0; 0.05 to 300 s |
| | IDMT (3) | | 0.5 to 20 s |
| Resolution | | | 10 ms or 1 digit |
| **Characteristic Times** | | | |
| Operation time | | | Pick-up < 40 ms at 2 Isr (typically 25 ms)<br>Inst. < 55 ms at 2 Isr (confirmed instantaneous) (typically 35 ms) |
| Overshoot time | | | < 35 ms at 2 Isr |
| Reset time | | | < 50 ms at 2 Isr (for T1 = 0) |

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Protection reset | P67N_x_101 | ■ | ■ |
| Protection blocking | P67N_x_113 | ■ | ■ |

**Outputs**

| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Instantaneous output (pick-up) | P67N_x_1 | ■ | ■ | |
| Delayed output | P67N_x_3 | ■ | ■ | ■ |
| Drop out | P67N_x_4 | ■ | ■ | |
| Instantaneous output (reverse zone) | P67N_x_6 | ■ | ■ | |
| Protection blocked | P67N_x_16 | ■ | ■ | |
| Instantaneous output at 0.8 Is0 | P67N_x_21 | ■ | ■ | |

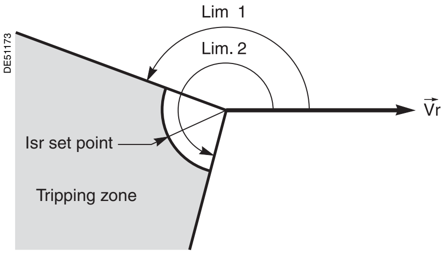
*x: unit number.*

*(1) Under reference conditions (IEC 60255-6).*

*(2) Setting ranges in TMS (Time Multiplier Setting) mode*
*Inverse (SIT) and IEC SIT/A: 0.04 to 4.20*
*Very inverse (VIT) and IEC VIT/B: 0.07 to 8.33*
*Very inverse (LTI) and IEC LTI/B: 0.01 to 0.93*
*Ext. inverse (EIT) and IEC EIT/C: 0.13 to 15.47*
*IEEE moderately inverse: 0.42 to 51.86*
*IEEE very inverse: 0.73 to 90.57*
*IEEE extremely inverse: 1.24 to 154.32*
*IAC inverse: 0.34 to 42.08*
*IAC very inverse: 0.61 to 75.75*
*IAC extremely inverse: 1.08 to 134.4.*

*(3) Only for standardized tripping curves of the IEC, IEEE and IAC types.*

# Directional Ground Fault - Type 3
ANSI Code 67N/67NC


DE51173
Lim 1
Lim. 2
$\vec{V}r$
Isr set point
Tripping zone

## Type 3 Operation

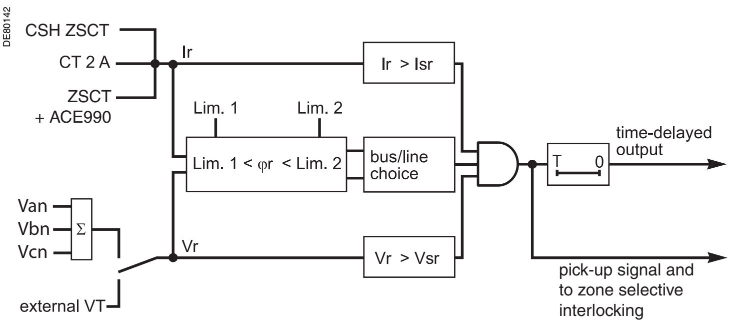
This protection operates like a ground fault protection function (ANSI 50N/51N) with an added angular direction criterion {*Lim.1*, *Lim.2*}. It is suitable for distribution networks in which the neutral grounding system varies according to the operational mode.

The tripping direction may be set at the bus end or line end.

Residual current is the current measured at the Sepam™ Ir input. It has a definite time delay (DT constant).

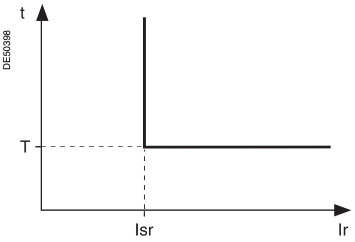
By choosing "0" as an Isr set point, the protection function behaves like a neutral voltage displacement protection function (ANSI 59N).

## Simplified Schematic


DE80142
CSH ZSCT
CT 2 A
ZSCT
+ ACE990
Ir
Ir > Isr
Lim. 1
Lim. 2
Lim. 1 < φr < Lim. 2
bus/line choice
time-delayed output
T 0
Van
Vbn
Vcn
Σ
Vr
Vr > Vsr
external VT
pick-up signal and to zone selective interlocking

### Definite Time Operation

Isr corresponds to the operating set point expressed in amps, and T corresponds to the protection operating delay.



*Definite time protection principle.*

# Directional Ground Fault - Type 3
## ANSI Code 67N/67NC

### Type 3 Characteristics

| | | |
|---|---|---|
| **Measurement Origin** | | |
| Setting range | | Ir<br>I'r<br>IrΣ (sum of the main phase channels) |
| **Tripping Zone Start Angle *Lim.1*** | | |
| Setting | | 0° to 359° |
| Resolution | | 1° |
| Accuracy | | ±3° |
| **Tripping Zone End Angle *Lim.2*** | | |
| Setting | | 0° to 359° (1) |
| Resolution | | 1° |
| Accuracy | | ±3° |
| **Tripping Direction** | | |
| Setting | | Line/bus |
| **Isr Set Point** | | |
| Setting (2) | With CSH zero sequence CT<br>(2 A rating) | 0.1 A to 30 A |
| | With 1 A CT | 0.005 INr ≤ Isr ≤ 15 INr (min. 0.1 A) |
| | With zero sequence CT + ACE990 (range 1) | 0.01 INr ≤ Isr ≤ 15 INr (min. 0.1 A) (3) |
| Resolution | | 0.1 A or 1 digit |
| Accuracy | | ±5% |
| Drop-out/pick-up ratio | | ≥ 95% |
| **Vsr Set Point** | | |
| Setting | On sum of 3 Vs | 2% $V_{LL}p$ ≤ Vsr ≤ 80% $V_{LL}p$ |
| | On external VT | 0.6% $V_{LL}p$ ≤ Vsr ≤ 80% $V_{LL}p$ |
| Resolution | | 0.1% for Vsr < 10%<br>1% for Vsr ≥ 10% |
| Accuracy | | ±5% |
| Drop-out/pick-up ratio | | ≥ 95% |
| **Time Delay T** | | |
| Setting | | instantaneous, 50 ms ≤ T ≤ 300 s |
| Resolution | | 10 ms or 1 digit |
| Accuracy | | ≤ 3% or ±20 ms at 2 Isr |
| **Characteristic Times** | | |
| Operation time | | pick-up < 40 ms at 2 Isr |
| | | instantaneous < 55 ms at 2 Isr |
| Overshoot time | | < 40 ms |
| Reset time | | < 50 ms |

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Reset protection | P67N_x_101 | ■ | ■ |
| Block protection | P67N_x_113 | ■ | ■ |

**Outputs**

| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Instantaneous output (pick-up) | P67N_x_1 | ■ | ■ | |
| Delayed output | P67N_x_3 | ■ | ■ | ■ |
| Drop-out | P67N_x_4 | ■ | ■ | |
| Instantaneous output (reverse zone) | P67N_x_6 | ■ | ■ | |
| Protection blocked | P67N_x_16 | ■ | ■ | |
| Instantaneous output at 0.8 Is0 | P67N_x_21 | ■ | ■ | |

**(1)** *Tripping zone Lim.2-Lim.1 should be 10° or more.*

**(2)** *For Isr = 0, the protection function behaves like a neutral voltage displacement protection function (59N).*

**(3)** *INr = k n where n = the zero sequence CT ratio and k = coefficient to be determined according to the wiring of the ACE990 (0.00578 ≤ k ≤ 0.04).*

### Standard Tripping Zone Setting (Line End)

The settings below are given for the usual applications in different types of neutral grounding system. The shaded boxes represent default settings.

| | Isolated Neutral | Impedant Neutral | Directly Grounded Neutral |
|---|---|---|---|
| *Lim.1* angle | 190° | 100° | 100° |
| *Lim.2* angle | 350° | 280° | 280° |

# Pole Slip
ANSI Code 78PS

*Protecting synchronous generators and motors against loss of synchronism*

## Description

This function provides protection against synchronization loss on synchronous machines. It is based on calculated active power.

The function is composed of two independent protection modules, based on:

- the equal-area criterion
- the power-swing criterion.

The tripping command can be issued by one or both criteria, depending on the parameter settings.

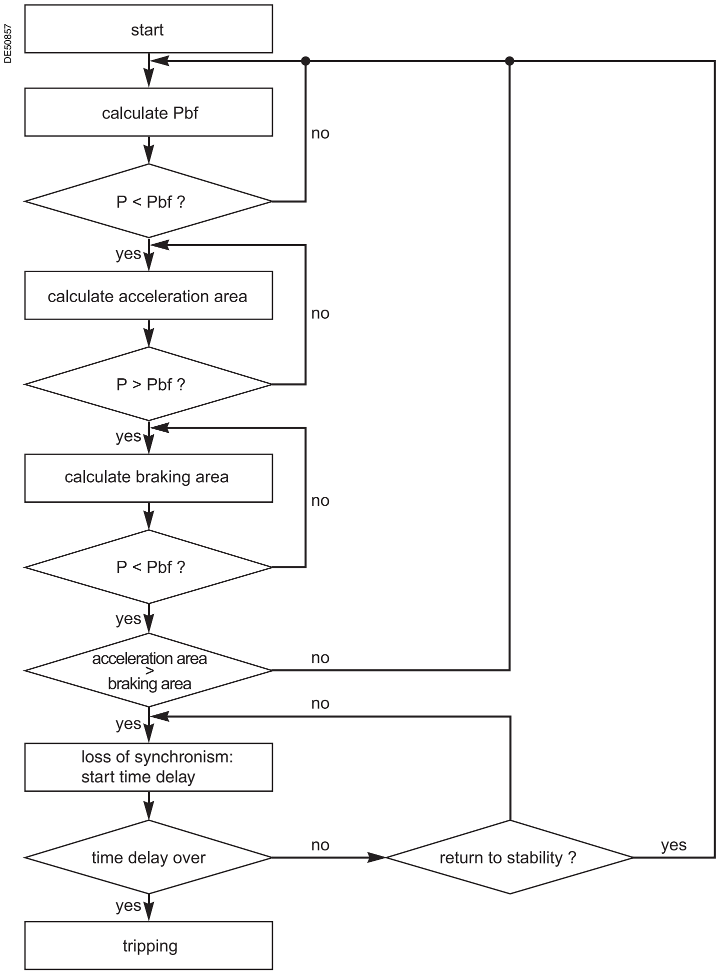
## Equal-Area Criterion

This function calculates the acceleration area when a fault appears and the braking area when the fault disappears. The tripping command is issued if the braking area is smaller than the acceleration area.

The function calculates an average power over four seconds (under steady state conditions). This is called power before fault (**Pbf)** and corresponds to the electrical power supplied by a generator or drawn by a motor. The function picks up when the instantaneous power is different than Pbf.

A time delay is available to delay tripping. If a "return to stability" is detected during the time delay, the function is reinitialized without tripping.

### Equal-Area Criterion Block Diagram


DE50857
start
calculate Pbf
no
P < Pbf ?
yes
calculate acceleration area
no
P > Pbf ?
yes
calculate braking area
no
P < Pbf ?
yes
acceleration area > braking area
no
no
yes
loss of synchronism: start time delay
time delay over
no
return to stability ?
yes
yes
tripping

# Pole Slip
ANSI Code 78PS

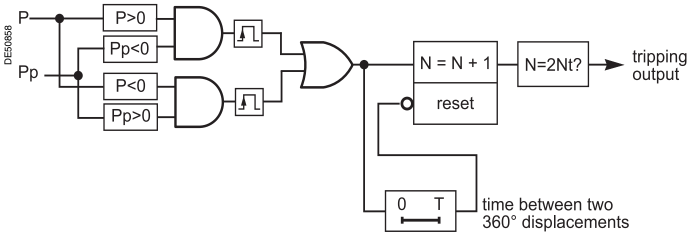
## Power-Swing Criterion

This function detects a change in the active power sign.

Two power swings are counted for each 360° of phase displacement between the electromotive force of the machine and the network. Power swings are detected by comparing the sign of the instantaneous power with that of the power 14 ms before, Pp. If the signs are different, a swing is counted.

The trip command is issued if the number of 360° displacements measured is equal to the set number. A time delay may be used to set a maximum time between two swings. This makes the function insensitive to low-frequency power oscillations.

## Power-Swing Criterion Block Diagram



## Current Transformers

Current transformers should be defined by a knee-point voltage
$V_k \geq (R_{CT} + R_W)\ 20\ I_{NS}$
where $R_{CT}$: CT internal resistance
Rw: wiring resistance CT rated secondary current

## Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Tripping Type Selection** | | | | |
| Setting range | Equal-area criterion<br>Power-swing criterion<br>Equal-area criterion and power-swing criterion | | | |
| **Equal-Area Criterion Time Delay** | | | | |
| Setting range | 100 ms ≤ T ≤ 300 s | | | |
| Accuracy (1) | ±2% or from –10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Number of 360° Displacements** | | | | |
| Setting range | 1 ≤ number of 360° displacements ≤ 30 | | | |
| Accuracy (1) | – | | | |
| Resolution | 1 360° displacement | | | |
| **Maximum Time Between Two 360° Displacements** | | | | |
| Setting range | 1 s ≤ T ≤ 300 s | | | |
| Accuracy (1) | ±2% or from –10 ms to +25 ms | | | |
| Resolution | 1 s or 1 digit | | | |
| **Characteristic Times** | | | | |
| Operation time | 38 ms to 2 Ps (2) | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P78PS_1_101 | ■ | ■ | |
| Protection blocking | P78PS_1_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P78PS_1_1 | ■ | ■ | |
| Delayed output | P78PS_1_3 | ■ | ■ | ■ |
| Protection blocked | P78PS_1_16 | ■ | ■ | |

*(1) Under reference conditions (IEC 60255-6).*
*(2) Ps = the maximum number of Poles slipped.*

## Example of Setting

Consider a 3.15 MVA generator in an industrial installation, connected to a network with a high short-circuit. Protection against losing synchronization is set up to trip according to the equal-area criterion and the power-swing criterion.

- tripping according to the equal-area criterion: 300 ms
- number of 360° displacements allowed: 2
- the maximum time between two swings is 10 seconds.

## Principle of Transient Stability

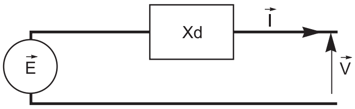
There are three types of stability in an electrical network:

- *steady state stability* concerns small variations in load and power. It is monitored by the power regulation functions
- *dynamic stability* concerns larger variations. It is ensured by the network regulation functions
- *transient stability* concerns major variations in power, such as during faults. It is monitored by action on the network, such as load shedding, source disconnection or independent operation of certain zones in the network.

Protection against synchronism loss can be used to detect cases of transient instability.

When a generator is connected to a network that has infinite power, the voltage across its terminals is imposed by the network. For a turbo-generator under steady state conditions, the internal impedance is equal to its longitudinal synchronous reactance Xd (the resistance and possible saturation of the magnetic circuit are not factors).

DE50639

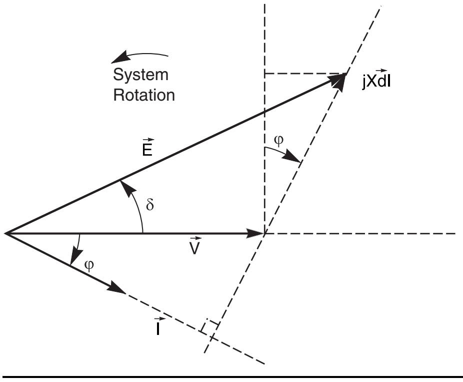


$$\vec{V} = \vec{E} - jXd\vec{I}$$

where E is the electromotive force of the machine
Xd: the synchronous reactance
V: the network voltage
I: the current supplied by the generator

If the generator supplies a current, the network voltage and the electromotive force of the machine are not in phase because of the synchronous reactance. This displacement is commonly called the internal angle of the machine or the *load angle,* β. When the electromotive force leads the network voltage, the internal angle is positive. When the electromotive force lags the network voltage, the internal angle is negative. The vector diagram is:

DE50640



The electrical power supplied by the machine to the network is: $P_e = 3VIpf$ .

On the vector diagram: $E\sin\delta = X_d(Ipf) = X_d\left(\frac{P_e}{3V}\right)$ .

As a function of the electromotive force, the internal angle and the synchronous reactance, the active power is: $P_e = \frac{3VE\sin\delta}{X_d}$.

This equation can be used to determine the electrical power supplied by the generator to the network, as a function of the internal angle and assuming that V, E and Xd are constant.

If losses are neglected (efficiency is close to 0.99), the relation between the mechanical power $P_m$ and the electrical power supplied $P_e$ is:

$$P_m = P_e + J\Omega\frac{d\Omega}{dt}$$

where J is the moment of inertia of the machine
Ω is the angular velocity of the rotating masses
$P_m$ is the mechanical power supplied by the driving machine

The velocity of the electric field is related to the mechanical velocity by the equation:

$$\Omega = \frac{\omega}{p}$$

where ω is the angular velocity of the electrical field
p is the number of pole pairs in the machine

In the remainder of this example, we will consider a machine with a single pair of poles, i.e. p = 1.

The relation between electrical and mechanical power becomes:

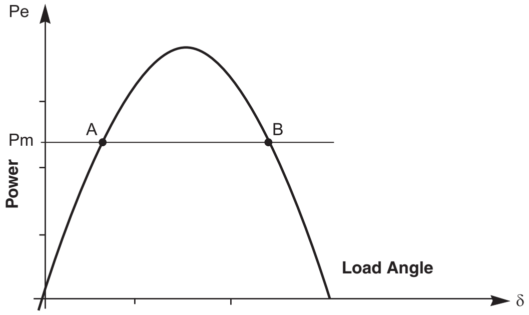
$$P_m = P_e + J\omega\frac{d\omega}{dt}\ .$$

Variations in speed are directly related to unbalances between the mechanical power and the electrical power supplied to the network.

$$\frac{d\omega}{dt} = \frac{P_m - P_e}{J\omega}.$$

Under steady state conditions (with no increase in speed), the electrical power (Pe) supplied to the network is equal to the mechanical power (Pm).

DE50641



The electrical power curve intersects the constant mechanical power line at two points (A and B).

- point A (stable operation):
  - if δ increases slightly with respect to its value at point A (the electromotive force leads the network voltage), the electrical power supplied to the network increases slightly. At a constant level of mechanical power:

$$\frac{d\omega}{dt} = \frac{P_m - P_e}{J\omega} < 0\ .$$

The machine slows as long as the electrical power supplied is not equal to the mechanical power, because the derivative of the velocity is negative. Electrically speaking, the electromotive force reduces its lead and consequently the angle δ.

  - if δ decreases slightly with respect to its value at point A (the electromotive force reduces its lead on the network voltage), the electrical power supplied to the network decreases slightly. At a constant level of mechanical power:

$$\frac{d\omega}{dt} = \frac{P_m - P_e}{J\omega} > 0\ .$$

The machine accelerates as long as the electrical power supplied is not equal to the mechanical power, because the derivative of the velocity is positive. Electrically speaking, the electromotive force increases its lead and consequently the angle δ.

- point B (unstable operation)
  - ☐ if δ increases slightly with respect to its value at point B (the electromotive force leads the network voltage), the electrical power supplied to the network decreases slightly. At a constant level of mechanical power:

$$\frac{d\omega}{dt} = \frac{P_m - P_e}{J\omega} > 0 .$$

The machine accelerates because the derivative of the velocity is positive. Electrically speaking, the electromotive force increases its lead and consequently the angle δ.

  - ☐ if δ decreases slightly with respect to its value at point B (the electromotive force reduces its lead on the network voltage), the electrical power supplied to the network increases slightly. At a constant level of mechanical power:

$$\frac{d\omega}{dt} = \frac{P_m - P_e}{J\omega} < 0 .$$

The machine slows because the derivative of the velocity is negative. Electrically speaking, the electromotive force reduces its lead and consequently the angle δ until it returns to point A.

When the machine passes point B, racing occurs. When a fault occurs, assuming it is a three-phase dead short across the generator terminals, the voltage across the machine terminals is equal to zero. Consequently, the electrical power supplied to the network is zero:

$$P_e = \frac{3VE\sin\delta}{X_d} = \frac{3\times 0\times E\sin\delta}{X_d} = 0 .$$

The regulation systems do not have enough time to react and the mechanical power across the machine terminals remain constant.

The fault results in an unbalance between the electrical power supplied to the network and the mechanical power:

$$\frac{d\omega}{dt} = \frac{P_m - P_e}{J\omega} > 0 .$$

If the derivative of the velocity is positive, the machine accelerates and the electromotive force begins to lead with respect to the voltage of the network. As long as the fault continues, the machine accelerates.
The variation in velocity is:

$$\int_{\omega_0}^{\omega_1} \omega d\omega = \frac{1}{J}\int_{t_0}^{t_1} P_m dt \quad \text{where}$$

the steady state conditions before the fault: $t_0$, $\omega_0$, $\delta_0$
the fault clearing conditions: $t_1$, $\omega_1$, $\delta_1$.

The integral $\int_{t_0}^{t_1} P_m dt$ is proportional to the acceleration of the machine.

It is commonly called the *acceleration area*.

When the fault is cleared, the voltage across the machine terminals is no longer zero. It is assumed that the network voltage, the load and the electromotive force are the same. In that the internal angle increased, the electrical power is **$P_e$(t)**.
Depending on the sign of **$P_m$ - $P_e$(t)**, the machine slows or continues to accelerate.

$$\int_{\omega_1}^{\omega_2} \omega d\omega = \frac{1}{J}\int_{t_1}^{t_2} (P_m - P_e(t))\, dt$$

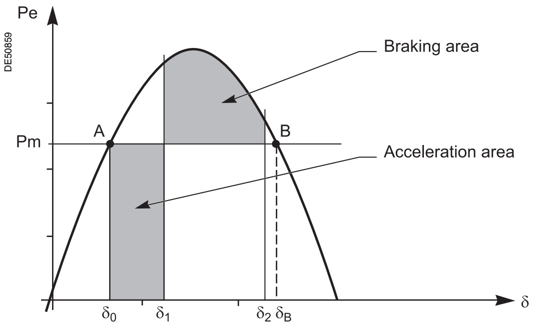
Generally, **$P_m$ - $P_e$(t) < 0**. This condition is not sufficient to recover stability.

- fault clearing with return to stability

the machine returns to its operating mode prior to the fault if the two integrals are equal:

$$\int_{t_1}^{t_2} (P_m - P_e(t))dt = \int_{t_0}^{t_1} P_m dt .$$

The integral $\int_{t_1}^{t_2} (P_m - P_e(t))dt$ is called the braking area.

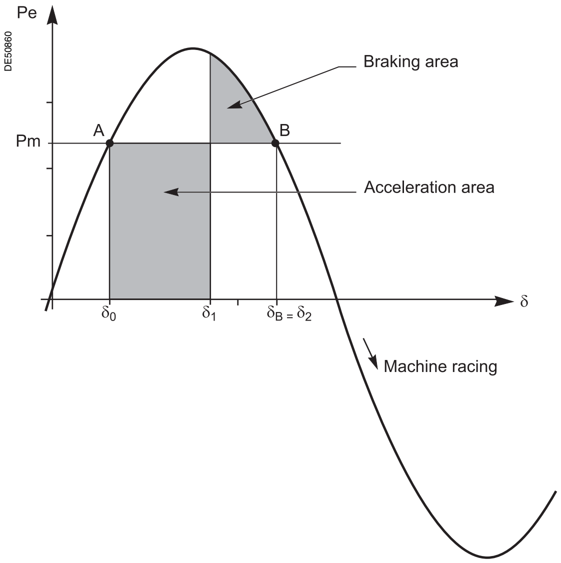


- fault clearing and loss of synchronization

During slowing, the machine passes point B and begins to accelerate again because beyond this point, **Pm - Pe(t) > 0**.

The braking area $\int_{t_1}^{t_2} (P_m - P_e(t))dt$ is not sufficient.

The machine starts to race and stability is lost. The machine alternates between phases during which it supplies electrical power and others where it draws power.



The situation presented here is also true for machines other than turbo-generators. In this case, the shape of $P_e$ as a function of the internal angle is different. The same is true when the voltage across the machine terminals does not drop to zero, or when there is a change in the load due to load shedding when the fault is cleared.
The situation for synchronous motors is identical to that of synchronous generators, except that instead of supplying power, they draw power. The network voltage leads the electromotive force. In this case, the above relationships must be inverted.

# Recloser
## ANSI Code 79

*Recloser with 1 to 4 shots to clear transients or semi-permanent faults on overhead lines.*

## Definition

**Reclaim Time**

The reclaim time is activated by a circuit breaker closing command given by the recloser. If no faults are detected before the end of the reclaim time, the initial fault is considered to be cleared. Otherwise a new reclosing step is initiated.

The delay must be longer than the longest reclosing step activation condition.

**Safety Time until Ready**

The safety time is activated by a manual circuit breaker closing command. The recloser is blocked for the duration of the time. If a fault occurs during this time, no reclosing steps are initiated and the circuit breaker remains permanently open.

**Dead Time**

Step *n* dead time is launched by breaking device tripping command given by the recloser during step n. The breaking device remains open throughout the time. At the end of the step n dead time, the n+1 step begins, and the recloser commands the circuit breaker closed.

## Description

An automation device is used to limit down time after tripping due to transient or temporary faults on overhead lines. The recloser automatically recloses the breaking device after a settable time delay. Recloser operation is easy to adapt for different operating modes by parameter setting.

The recloser is ready to operate if all of the following conditions are met:

- "switchgear control" function activated and recloser in service (not blocked by the recloser blocking logic input)
- circuit breaker closed
- the safety time is not running
- none of the recloser blocking conditions is true (trip circuit fault, control fault, SF6 pressure drop)

**Recloser Steps**

The recloser will step under any of the following conditions:

- **case of a fault that is not cleared**: following instantaneous or time-delayed tripping by the protection unit, activation of the dead time associated with the first active cycle. At the end of the dead time, a closing command is given, which activates the reclaim time. If the protection unit detects the fault before the end of the time delay, a tripping command is given and the following reclosing step is activated. After all the active shots have run, a final trip command is given if the fault still persists and a message will appear on the display
- **case of a cleared fault**: Following a reclosing command, if the fault does not appear after the reclaim time has run out, the recloser reinitializes and a message appears on the display (see example 1)
- **closing on a fault**. If the circuit breaker closes on a fault, or if the fault appears before the end of the safety time delay, the recloser is blocked. A final trip message is issued

**Recloser Block Conditions**

The recloser is blocked according to the following conditions:

- voluntary open or close command
- recloser put out of service
- receipt of a block command on the logic input
- activation of the breaker failure, such as trip circuit fault, control fault, SF6 pressure drop
- opening of the circuit breaker by a protection unit that does not run reclosing cycles (such as frequency protection), by external tripping or by a function set up not to activate reclosing cycles.

In such cases, a final trip message appears.

**Extending the dead time**

If, during a reclosing step, it is impossible to reclose the circuit breaker because recharging is not finished(1), the dead time can be extended up to the time the circuit breaker is ready to carry out an "Open-Close-Open" cycle. The maximum time added to the dead time is adjustable (Twait_max). If, at the end of the maximum waiting time, the circuit breaker is still not ready, the recloser is blocked (see example 5).

*(1) Following a drop in auxiliary voltage, recharging time is longer*

# Recloser
## ANSI Code 79

### Characteristics

| **Settings** | | |
|---|---|---|
| **Number of Steps** | | |
| Setting range | | 1 to 4 |
| **Activation of Shot 1** | | |
| Protection 50/51 units 1 to 4 | | inst. / delayed / no activation |
| Protection 50N/51N units 1 to 4 | | inst. / delayed / no activation |
| Protection 67 units 1 to 2 | | inst. / delayed / no activation |
| Protection 67N/67NC units 1 to 2 | | inst. / delayed / no activation |
| Logic equations or Logipam outputs V_TRIPCB | | active/inactive |
| **Activation of Shots 2, 3, and 4** | | |
| Protection 50/51 units 1 to 4 | | inst. / delayed / no activation |
| Protection 50N/51N units 1 to 4 | | inst. / delayed / no activation |
| Protection 67 units 1 to 2 | | inst. / delayed / no activation |
| Protection 67N/67NC units 1 to 2 | | inst. / delayed / no activation |
| Logic equations or Logipam outputs V_TRIPCB | | active/inactive |
| **Time Delays** | | |
| Reclaim time | | 0.1 to 300 s |
| Dead time | Shot 1 | 0.1 to 300 s |
| | Shot 2 | 0.1 to 300 s |
| | Shot 3 | 0.1 to 300 s |
| | Shot 4 | 0.1 to 300 s |
| Safety time until ready | | 0 to 60 s |
| Maximum additional dead time | | 0.1 to 60 s |
| Accuracy [2] | | ±2% or ±25 ms |
| Resolution | | 10 ms |

**Inputs**

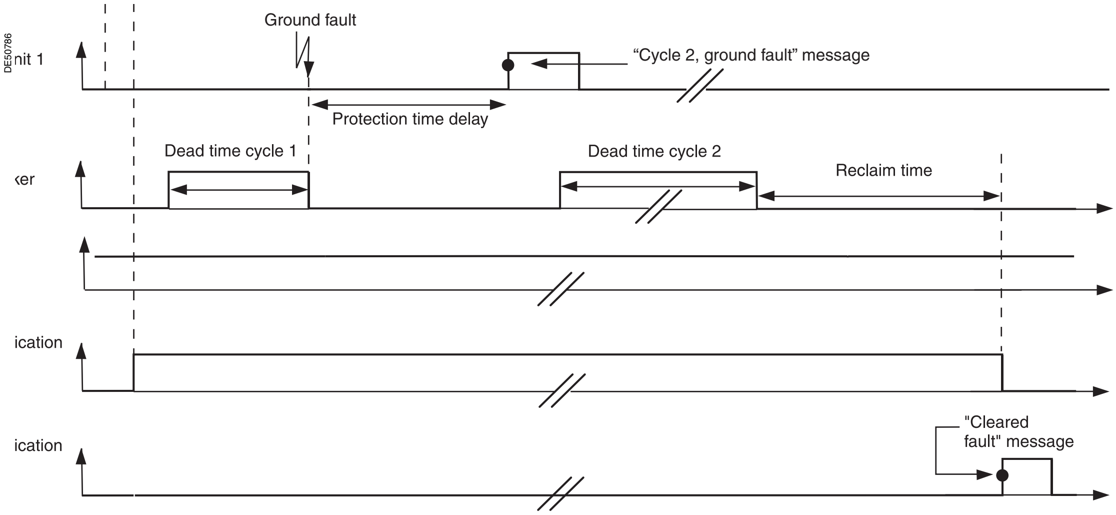
| **Designation** | **Syntax** | **Equations** | **Logipam** |
|---|---|---|---|
| Protection blocking | P79_1_113 | ■ | ■ |

**Outputs**

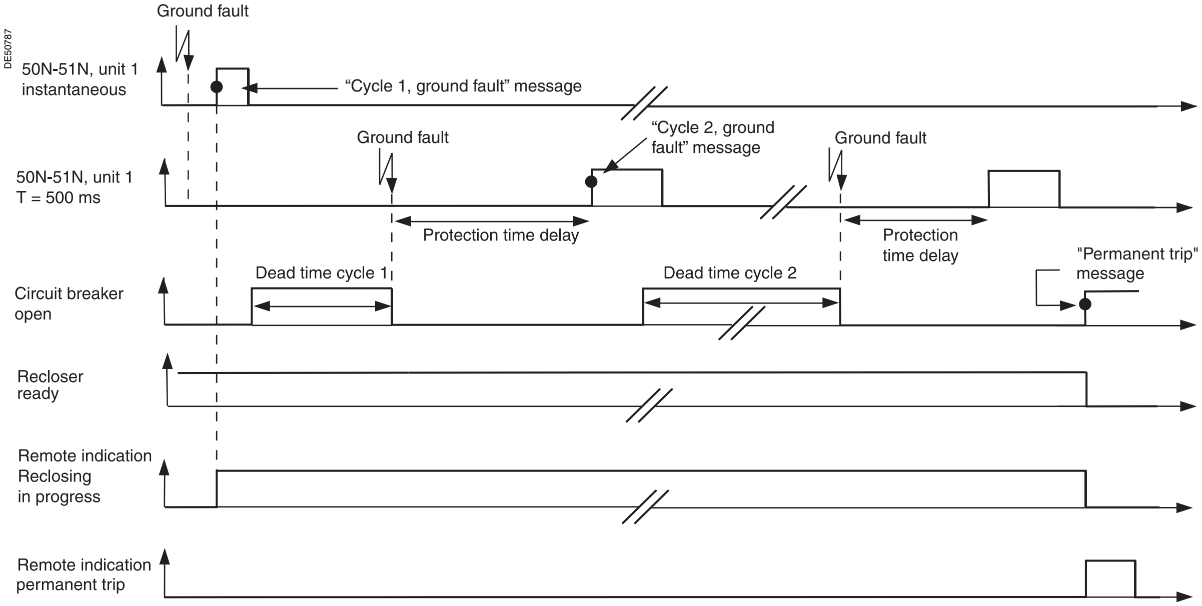
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
|---|---|---|---|---|
| Recloser in service | P79 _1_201 | ■ | ■ | ■ |
| Recloser ready | P79 _1_202 | ■ | ■ | ■ |
| Cleared fault | P79 _1_203 | ■ | ■ | ■ |
| Final trip | P79 _1_204 | ■ | ■ | ■ |
| Closing by recloser | P79 _1_205 | ■ | ■ | |
| Reclosing step 1 | P79 _1_211 | ■ | ■ | ■ |
| Reclosing step 2 | P79 _1_212 | ■ | ■ | ■ |
| Reclosing step 3 | P79 _1_213 | ■ | ■ | ■ |
| Reclosing step 4 | P79 _1_214 | ■ | ■ | ■ |

***(1)** Under reference conditions (IEC 60255-6).*

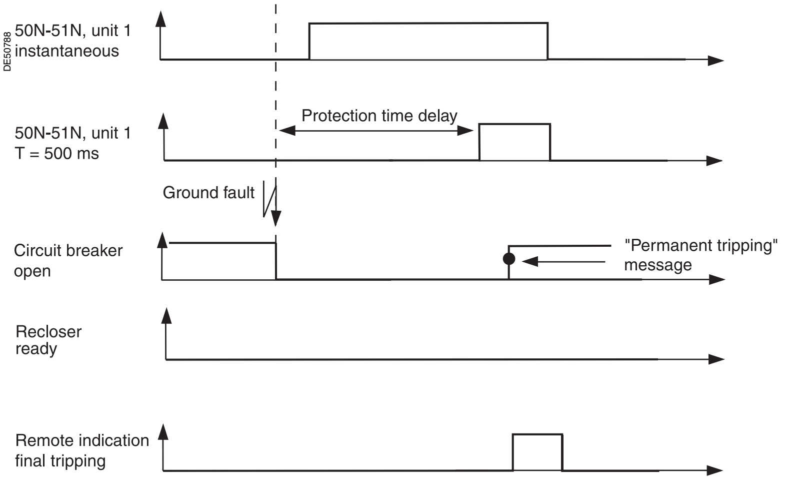
### Example 1. Fault cleared after the second shot


DE50786
nit 1
Ground fault
"Cycle 2, ground fault" message
Protection time delay
ker
Dead time cycle 1
Dead time cycle 2
Reclaim time
ication
ication
"Cleared
fault" message

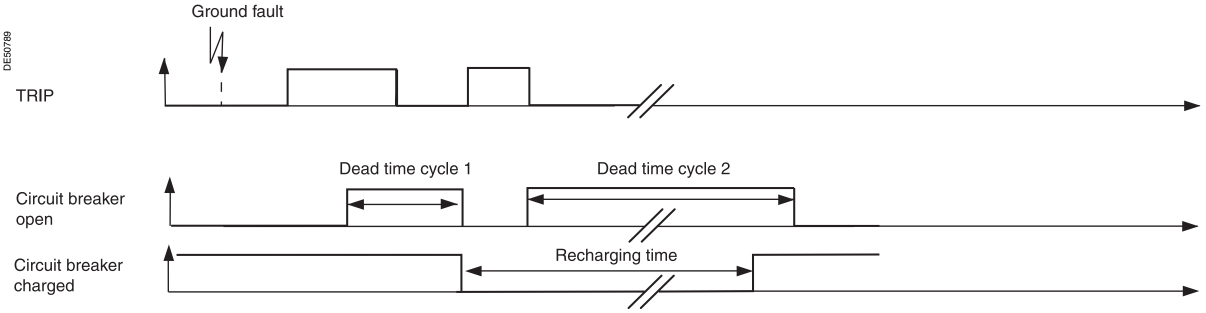
### Example 2. Fault not cleared


DE50787
Ground fault
50N-51N, unit 1
instantaneous
"Cycle 1, ground fault" message
50N-51N, unit 1
T = 500 ms
Ground fault
"Cycle 2, ground
fault" message
Ground fault
Protection time delay
Protection
time delay
Circuit breaker
open
Dead time cycle 1
Dead time cycle 2
"Permanent trip"
message
Recloser
ready
Remote indication
Reclosing
in progress
Remote indication
permanent trip

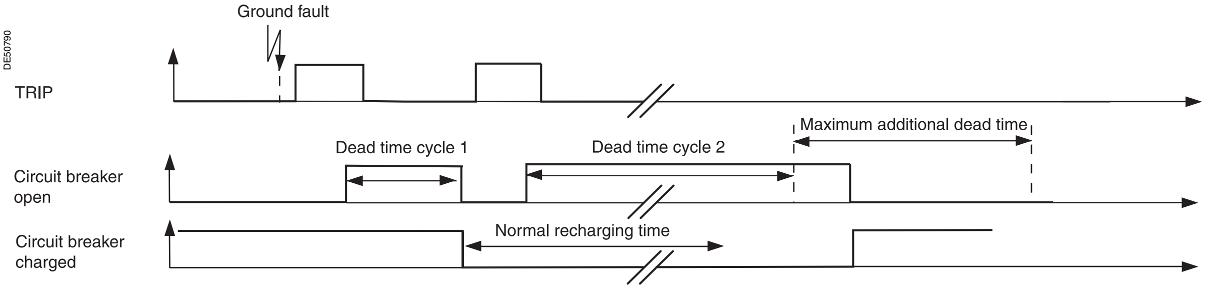
## Example 3. Closing on a fault


DE50788
50N-51N, unit 1 instantaneous
Protection time delay
50N-51N, unit 1 T = 500 ms
Ground fault
Circuit breaker open
"Permanent tripping" message
Recloser ready
Remote indication final tripping

## Example 4. No extension of dead time


Ground fault
DE50789
TRIP
Dead time cycle 1
Dead time cycle 2
Circuit breaker open
Recharging time
Circuit breaker charged

## Example 5. Extension of dead time


Ground fault
DE50790
TRIP
Maximum additional dead time
Dead time cycle 1
Dead time cycle 2
Circuit breaker open
Normal recharging time
Circuit breaker charged

# Overfrequency
ANSI Code 81H

*Detection of abnormally high frequencies.*

## Description

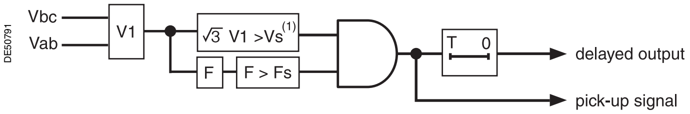
Detection of abnormally high frequency compared to the rated frequency, to monitor power supply quality or protect a generator against overspeeds.

The frequency is calculated using voltage Van or Vab when only one voltage is connected. Otherwise the positive sequence voltage V1 is used to procure greater stability. It is compared to the Fs set point.

The protection function is blocked if the voltage used for calculations is under the adjustable set point Vs.

The protection includes a definite time delay T.

## Block Diagram



## Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Measurement Origin** | | | | |
| Setting range | Main channels ($V_{LL}$) / Additional channels ($V_{LL}$') | | | |
| **Fs Set Point** | | | | |
| Setting range | 50 to 55 Hz or 60 to 65 Hz | | | |
| Accuracy (1) | ±0.01 Hz | | | |
| Resolution | 0.1 | | | |
| Pick up / drop out difference | 0.25 Hz | | | |
| **Time Delay T** | | | | |
| Setting range | 100 ms to 300 s | | | |
| Accuracy (1) | ±2% or ±25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Advanced Settings** | | | | |
| **Vs Set Point** | | | | |
| Setting range | 20% to 50% $V_{LLN}$ | | | |
| Accuracy (1) | 2% | | | |
| Resolution | 1% | | | |
| **Characteristic Times** | | | | |
| Operation time | Pick-up < 90 ms from Fs -0.5 Hz to Fs +0.5 Hz | | | |
| Overshoot time | < 50 ms from Fs -0.5 Hz to Fs +0.5 Hz | | | |
| Reset time | < 55 ms from Fs +0.5 Hz to Fs -0.5 Hz | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P81H_x_101 | ■ | ■ | |
| Protection blockingblock | P81H_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P81H_x_1 | ■ | ■ | |
| Delayed output | P81H_x_3 | ■ | ■ | ■ |
| Protection blockblocked | P81H_x_16 | ■ | ■ | |

*x: unit number.*
***(1)** Under reference conditions (IEC 60255-6) and df/dt < 3 Hz/s.*

# Underfrequency
ANSI Code 81L

*Detecting abnormally low frequency for load shedding using a metric frequency criterion.*

## Description

This function detects abnormally low frequency and compares it to the rated frequency in order to monitor power supply quality. The protection can be used for overall tripping or load shedding.

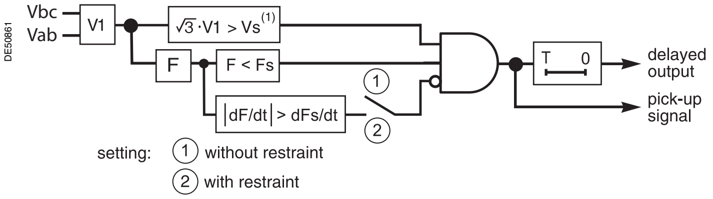
The frequency is calculated using voltage Van or Vab when only one voltage is connected.  Otherwise the positive sequence voltage V1 is used to provide greater stability. It is compared to the frequency set point, Fs.

The protection function is blocked if the value of voltage used for calculations is below the adjustable set point Vs.

Protection stability is provided in the event of the loss of the main source and presence of remnant voltage by a restraint in the event of a continuous decrease of the frequency.

The protection includes a definite (DT) time delay T.

## Block Diagram



## Characteristics

| | | | | |
|---|---|---|---|---|
| **Settings** | | | | |
| **Measurement Origin** | | | | |
| Setting range | Main channels ($V_{LL}$) / Additional channels ($V_{LL}$') | | | |
| **Fs Set Point** | | | | |
| Setting range | 40 to 50 Hz or 50 to 60 Hz | | | |
| Accuracy (1) | ±0.01 Hz | | | |
| Resolution | 0.1 | | | |
| Pick up / drop out difference | 0.25 Hz | | | |
| **Time Delay T** | | | | |
| Setting range | 100 ms to 300 s | | | |
| Accuracy (1) | ±2% or ±25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Advanced Settings** | | | | |
| **Vs Set Point** | | | | |
| Setting range | 20% to 50% $V_{LLN}$ | | | |
| Accuracy (1) | 2% | | | |
| Resolution | 1% | | | |
| **Restraint on Frequency Variation** | | | | |
| Setting | With / without | | | |
| dFs/dt set point | 1 Hz/s to 15 Hz/s | | | |
| Accuracy (1) | ±1 Hz/s | | | |
| Resolution | ±1 Hz/s | | | |
| **Characteristic Times** | | | | |
| Operation time | Pick-up < 90 ms from Fs +0.5 Hz to Fs -0.5 Hz | | | |
| Overshoot time | < 50 ms from Fs +0.5 Hz to Fs -0.5 Hz | | | |
| Reset time | < 55 ms from Fs -0.5 Hz to Fs +0.5 Hz | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P81L_x_101 | ■ | ■ | |
| Protection blockingblock | P81L_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P81L_x_1 | ■ | ■ | |
| Delayed output | P81L_x_3 | ■ | ■ | ■ |
| Protection blocked | P81L_x_16 | ■ | ■ | |

*x: unit number.*
***(1)** Under reference conditions (IEC 60255-6) and df/dt < 3 Hz/s.*

# Rate of Change of Frequency (df/dt)

## ANSI Code 81R

*Protection function based on the calculation of the frequency variation, used to rapidly disconnect a source supplying a network or to control load shedding.*

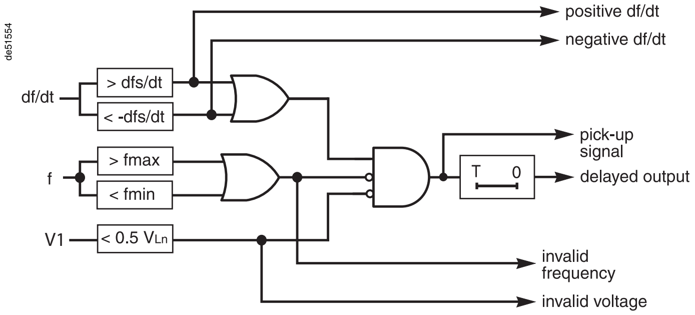
### Operation

The rate of change of frequency protection function is complementary to the under and overfrequency protection functions in detecting network configurations that require load shedding or disconnection.

The function is activated when the "rate of change of frequency" df/dt of the positive sequence voltage is higher than a set point. It includes a definite time (DT) delay.

The protection function operates if:
- the positive sequence voltage is greater than 50% of the rated phase-to-neutral voltage
- the network frequency is between 42.2 Hz and 56.2 Hz for 50 Hz networks and between 51.3 Hz and 65 Hz for 60 Hz networks.

### Block Diagram



### Characteristics

| | | | | |
|---|---|---|---|---|
| **Settings** | | | | |
| **dfs/dt Set Point** | | | | |
| Setting range | 0.1 to 10 Hz/s | | | |
| Accuracy (1) | ±5% or ±0.1 Hz | | | |
| Resolution | 0.01 Hz | | | |
| Drop out/pick up ratio | 93% | | | |
| **Temporization** | | | | |
| Setting range | 0.15 to 300 s | | | |
| Accuracy (1) | ±2% or -10% +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Characteristic Times (1)** | | | | |
| Operation time | Pick-up < 150 ms (typically 130 ms) | | | |
| Overshoot time | < 100 ms | | | |
| Reset time | < 100 ms | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P81R_x_101 | ■ | ■ | |
| Protection blockingblock | P81R_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Instantaneous output (pick-up) | P81R_x_1 | ■ | ■ | |
| Tripping output | P81R_x_3 | ■ | ■ | ■ |
| Protection blocked | P81R_x_16 | ■ | ■ | |
| Invalid voltage | P81R_x_42 | ■ | ■ | |
| Invalid frequency | P81R_x_43 | ■ | ■ | |
| Positive df/dt | P81R_x_44 | ■ | ■ | |
| Negative df/dt | P81R_x_45 | ■ | ■ | |

*x: unit number.*

***(1)** Under reference conditions (IEC 60255-6) and df/dt < 3 Hz/s.*

# Rate of Change of Frequency (df/dt)

## ANSI Code 81R

### Disconnection Application

The rate of change of frequency (df/dt) function can be used on service entrance mains that include generators that operate in parallel with the utility grid. If, under these conditions, the utility experiences an outage, the co-gen will temporarily try to back feed the utility system. If the power flow from the utility prior to the service switchgear main was not a zero value, the generator frequency changes.

The df/dt protection function detects an islanded generator operation more rapidly than conventional frequency Protection Functions.

Other disturbances such as short-circuits, load fluctuations and switching may cause changes of frequency. The low set point may be reached temporarily due to these disturbances and a time delay is necessary. In order to maintain the advantage of the speed of the df/dt protection (compared to conventional frequency protection functions), a second, higher set point with a short time delay may be added.

The actual rate of change of frequency is not constant. Often, the rate is highest at the beginning of the disturbance and decreases afterward. This extends the tripping time of frequency protection functions but does not affect the tripping time of the rate of change of frequency protection function.

**Low Set Point**

- Follow the utility's instructions, if there are any.
- If there are no utility instructions, proceed as follows:
  - ☐ if the maximum rate of change of frequency on the network under normal conditions is known, dfs/dt should be set above it.
  - ☐ if no information on the network is available, the low set point may be set according to generator data.
    A good approximation of the rate of change of frequency after a utility failure resulting in a load variation $\Delta P$ is:

$$\frac{df}{dt} = \frac{\Delta P \times fn}{2 \times Sn \times H}$$

where Sn: rated power
fn: rated frequency
H: inertia constant

Typical value of the inertia constant (in MWs/MVA):
$0.5 \le H \le 1.5$ for diesel and low-power generators ($\le$ 2 MVA)
$2 \le H \le 5$ for gas turbines and medium-power generators ($\le$ 40 MVA)

$$H = \frac{J \times \Omega^2}{2 \times Sn}$$

where J: moment of inertia
$\Omega$: machine speed

**Examples**

| | | |
|---|---|---|
| Rated power | 2 MVA | 20 MVA |
| Inertia constant | 0.5 MWs/MVA | 2 MWs/MVA |
| Power variation | 0.1 MVA | 1 MVA |
| df/dt | –2.5 Hz/s | –0.6 Hz/s |

**Low Set Point Delay Setting**

For good protection stability during short-circuits or transient disturbances, the recommended time delay is 300 ms or more. If an automatic recloser is in service upstream of the installation, the detection of an islanded generator operation and the opening of the inter-tie circuit breaker should take place during the recloser isolation time.

**High Set Point**

The second set point may be chosen so that the rate of change of frequency tripping curve remains below the under and overfrequency protection curves.
If the frequency protection units are set to fn±0.5Hz and the low set point of the rate of change of frequency is T, the high set point may be set to 0.5/T.

**High Set Point Delay Setting**

No particular recommendantions.

**Setting recommendations when no other information is available**

| Settings | Generator Power | 2 to 10 MVA | > 10 MVA |
|---|---|---|---|
| Low set point | dfs/dt | 0.5 Hz/s | 0.2 Hz/s |
| | T | 500 ms | 500 ms |
| High set point | dfs/dt | 2.5 Hz/s | 1 Hz/s |
| | T | 150 ms | 150 ms |

# Rate of Change of Frequency (df/dt)

ANSI Code 81R

**Operating Precautions:**
When the generator connects to the network, power oscillations may occur until the generator becomes fully synchronized. The df/dt protection function senses this phenomenon, so it is advisable to block the protection unit for a few seconds after circuit breaker closing.

## Load Shedding Application

The df/dt protection function may also be used for load shedding in combination with underfrequency protection. In such cases, it is used on the installation bus. Only negative frequency derivatives are to be used.

Two principles are available:

- **Acceleration of load shedding**: The rate of change of frequency protection functions controls load shedding. It acts faster than underfrequency protection functions and the value measured (df/dt) is directly proportional to the load to be shed
- **Load shedding block**: This principle is included in underfrequency protection functions. It consists of activating the frequency variation restraint and does not call for implementation of the rate of change of frequency protection function.

# Machine Differential

## ANSI Code 87M

*Phase-to-phase short-circuit protection for generators and motors.*

## Description

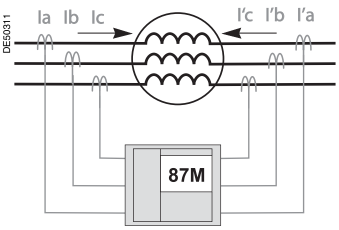
This is phase-to-phase short-circuit protection and is based on phase by phase comparison of the currents on motor and generator windings.

This function enables if the difference in current is greater than the set point defined by:

- a percentage-based curve
- a differential curve (high set point).

Tripping restraint ensures stability due to:

- detection of an external fault or machine starting
- detection of CT saturation
- fast detection of CT loss
- detection of transformer energizing.



**Percentage-Based Differential**

The percentage-based tripping characteristic compares the through current to the differential current.

According to the current measurement convention, shown in the diagram and respecting the recommended wiring system, the differential and through currents are calculated by:

- differential current:

$$Idx = \left|\vec{I}_x + \vec{I'}_x\right| \quad \text{where } x = a, b, c$$

- through current

$$Itx = \frac{\left|\vec{I}_x - \vec{I'}_x\right|}{2} \quad \text{where } x = a, b, c$$

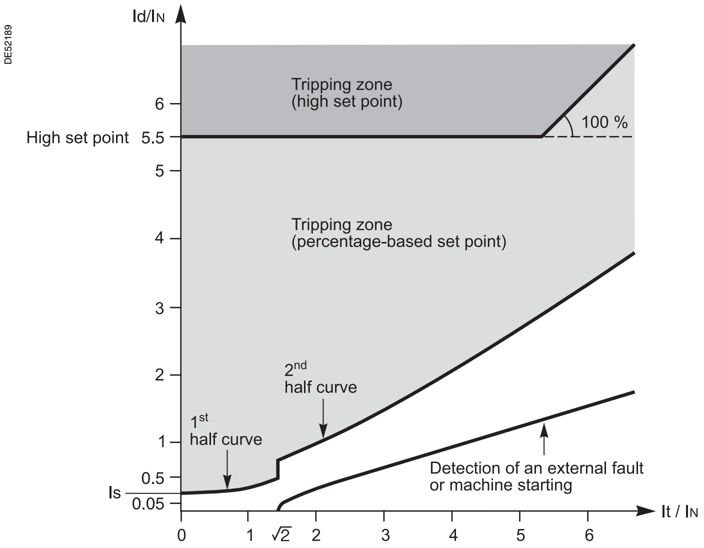
The percentage-based characteristic is made up to two half curves defined according to the following formulas:

- 1st half curve depending on the Is set point

$$Idx^2 - \frac{Itx^2}{32} > Is^2 \quad \text{where } 0 \le Itx \le \sqrt{2}\,I_N \text{ and } x = a, b, c$$

- 2nd half curve

$$\frac{Idx^2}{8} - \frac{Itx^2}{32} > (0.005\ I_N)^2 \quad \text{where } \sqrt{2}\,I_N < Itx \text{ and } x = a, b, c.$$



**Differential High Set Point.**

To avoid any delay for major asymmetrical faults, a differential high set point, without restraint, is used.

The characteristic of this set point is:

$$Idx > 5.5\ I_N \quad \text{and} \quad \frac{Idx}{Itx} > 1 \quad \text{where } x = a, b, c$$

**Tripping Restraints**

The following are applications for machine differential restraint:

**1 Restraint for external faults or machine starting**

During starting or an external fault, the through current is much higher than 1.5 $I_N$. As long as the CTs do not saturate, the differential current is low. This transient state is detected by the following characteristic:

$$\frac{Idx^2}{2} - \frac{Itx^2}{32} < -(0.25\ I_N)^2 \quad \text{where } x = a, b, c$$

An external fault can be followed by a short, but high differential current, that is why a 200 ms restraint is used to ensure protection stability for this type of fault.

**2 Restraint on CT saturation**

CT saturation can result in a false differential current and nuisance tripping. The restraint analyses the asymmetry of the signals and restrains the tripping command if a CT is saturated.

**3 Restraint on CT loss**

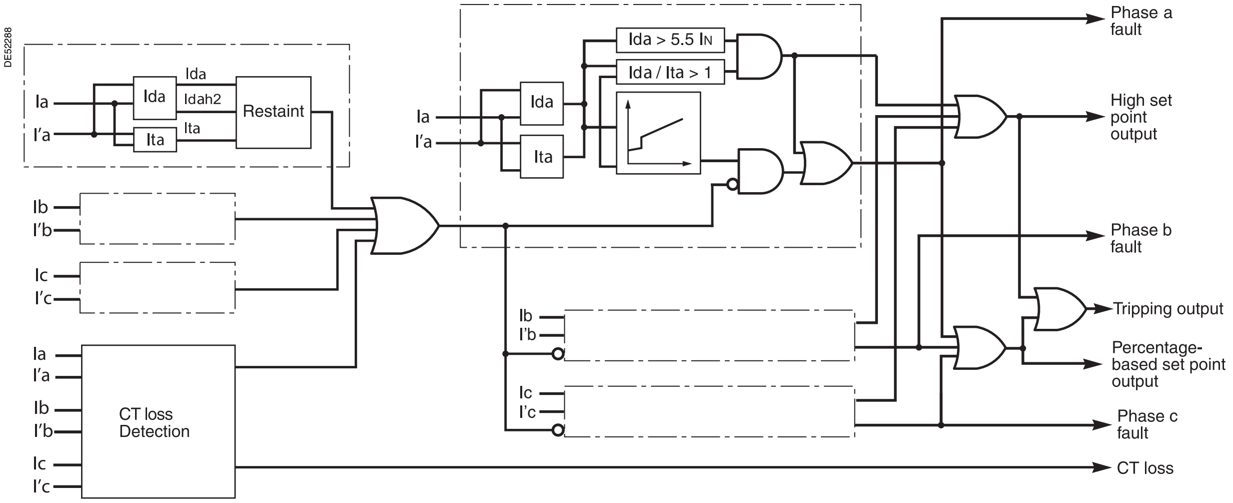
CT loss can result in a false differential current and nuisance tripping. This restraint is the means to detect a measurement that abnormally drops to zero (sample analysis).

**4 Restraint on transformer energizing**

- ☐ this restraint ensures that the second harmonic level of the differential current is greater than 15 %:

$$\frac{Idxh2}{Idx} > 0.15 \quad \text{where } x = a, b, c.$$

## Block Diagram


DE52288
Ia
I'a
Ida
Idah2
Ita
Restaint
Ib
I'b
Ic
I'c
CT loss
Detection
Ida > 5.5 IN
Ida / Ita > 1
Phase a fault
High set point output
Phase b fault
Tripping output
Percentage-based set point output
Phase c fault
CT loss

## Sizing Phase-Current Transformers

Current transformers should be defined by a knee-point voltage
$V_k \geq (R_{CT} + R_w).20.I_{N2}$.

Generators are characterized by large X/R ratio's. The rule of thumb is to use the highest possible accuracy class. A completely offset short circuit current requires the ct to support (1+X/R) times the calculated voltage. In many applications it is not possible to completely avoid saturation. Under these conditions it is helpful to have machine differential ct's with the same knee point voltage.

The equations apply to the phase current transformers placed on either side of the machine.

**$I_{N2}$** is the CT rated secondary current.
**$R_{CT}$** is the CT internal resistance.
**$R_w$** is the resistance of the CT load and wiring.

The setting range of the Is set point depends on the rated values of the CTs on the main channels Ia, Ib, Ic and the additional channels I'a, I'b, I'c. The setting range is the intersection of [0.05 $I_N$ 0.5 $I_N$] with [0.05 $I'_N$ 0.5 $I'_N$]. When the rated values are identical, the setting range is optimum. If there is no intersection, the function cannot be used.

## Characteristics

| | | | | |
|---|---|---|---|---|
| **Settings** | | | | |
| **Is Set Point** | | | | |
| Setting range | max (0.05 $I_{NA}$; 0.05 $I_{NB}$) ≤ Is ≤ min (0.5 $I_{NA}$; 0.5 $I_{NB}$) | | | |
| Accuracy (1) | 5% Is or 0.4% $I_N$ | | | |
| Resolution | 1 A or 1 digit | | | |
| Drop out/pick up ratio | 93.5% | | | |
| **Advanced Settings** | | | | |
| **Pick-up of restraint on CT loss** | | | | |
| Setting range | On / off | | | |
| **Characteristic Times** | | | | |
| Operation time | Operation time of differential current function | | | |
| Overshoot time | < 40 ms | | | |
| Reset time | < 35 ms | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Protection reset | P81L_x_101 | ■ | ■ | |
| Protection blockingblock | P81L_x_113 | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Protection output | P87M_1_3 | ■ | ■ | ■ |
| Phase a fault | P87M_1_7 | ■ | ■ | |
| Phase b fault | P87M _1_8 | ■ | ■ | |
| Phase c fault | P87M _1_9 | ■ | ■ | |
| Protection blocked | P87M_1_16 | ■ | ■ | |
| High set point | P87M_1_33 | ■ | ■ | |
| Percentage-based set point | P87M_1_34 | ■ | ■ | |
| CT loss | P87M_1_39 | ■ | ■ | |

***(1)** Under reference conditions (IEC 60255-6).*

# Transformer Differential
## ANSI Code 87T

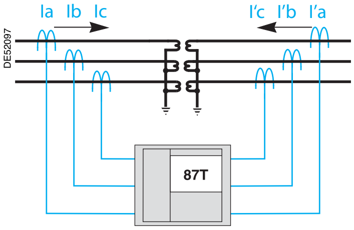
*Phase-to-phase short-circuit protection for transformers and transformer-machine units (2 windings)*

### Operation

This protection function protects the zone between the CTs for the main currents Ia, Ib, Ic on the one hand and the CTs for the additional currents I'a, I'b, I'c on the other.

It adjusts both the amplitude and phase of the currents in each winding according to the vector shift and the transformer rated power, as well as the set voltage and current values.

It then compares the matched currents phase by phase.



DE52097
Ia Ib Ic
I'c I'b I'a
87T

According to the current measurement convention shown in the diagram and respecting the recommended wiring system, the differential currents Id and through currents It are calculated using the matched currents Im and I'm.

- Differential current: $\mathbf{Idx} = \left|\vec{I}\mathbf{xm} + \vec{I}'\mathbf{xm}\right|$ where x = a, b, or c
- Through current: $\mathbf{Itx} = \mathbf{max}\left(\left|\vec{I}\mathbf{xm}\right|, \left|\vec{I}'\mathbf{xm}\right|\right)$ where x = a, b, or c

The function picks up if the differential current of at least one phase is greater than the operating threshold defined by:

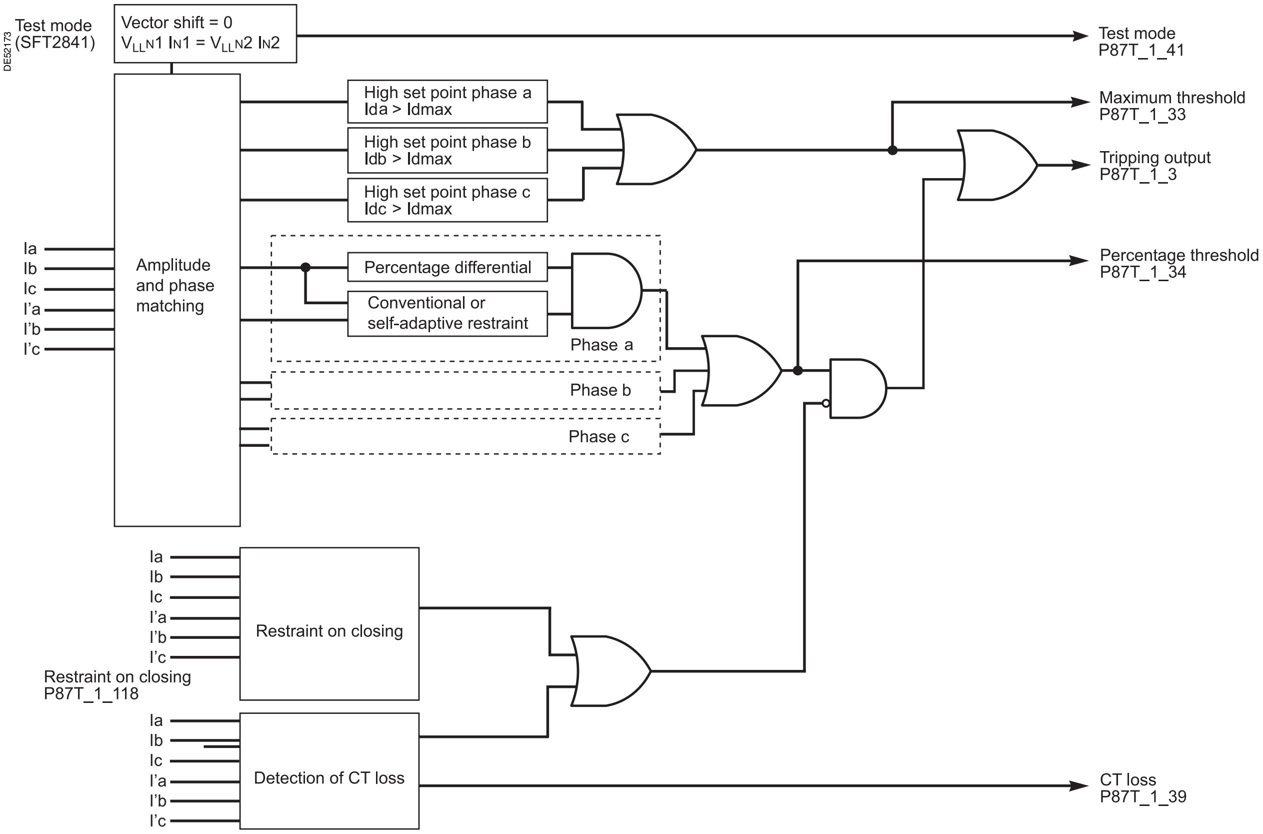
- a high adjustable differential current set point, without tripping restraint
- an adjustable percentage-based characteristic with two slopes
- a low adjustable differential current set point.

Stability is ensured by the following tripping restraints:

- a self-adaptive or conventional harmonic restraint
- a transfomer-energization restraint
- a CT-loss restraint.

The high tripping set point is not restrained.

### Block Diagram



DE52173
Test mode
(SFT2841)
Vector shift = 0
V_LLN1 IN1 = V_LLN2 IN2
Test mode
P87T_1_41
High set point phase a
Ida > Idmax
High set point phase b
Idb > Idmax
High set point phase c
Idc > Idmax
Maximum threshold
P87T_1_33
Tripping output
P87T_1_3
Ia
Ib
Ic
I'a
I'b
I'c
Amplitude and phase matching
Percentage differential
Conventional or self-adaptive restraint
Phase a
Percentage threshold
P87T_1_34
Phase b
Phase c
Ia
Ib
Ic
I'a
I'b
I'c
Restraint on closing
Restraint on closing
P87T_1_118
Ia
Ib
Ic
I'a
I'b
I'c
Detection of CT loss
CT loss
P87T_1_39

## Definitions

The terms winding 1 and winding 2 are used in the following manner:

- winding 1: corresponds to the circuit to which the main currents Ia, Ib, Ic, and the voltage measurements Van, Vbn, Vcn, Vab, or Vbc are connected
- winding 2: corresponds to the circuit to which the additional currents I'a, I'b, I'c are connected.

The transformer electrical parameters must be set on the "Particular characteristics" screen in the SFT2841 software:

- winding 1 voltage: $V_{LL}N1$
- winding 2 voltage: $V_{LL}N2$
- vector shift
- transformer rated power S.

To assist during the setup procedure, the screen shows:

- the transformer rated current value for windings 1 and 2: IN1, IN2
- the value set on the "CT-VT" screen for the base current IB of winding 1
- the value calculated using the transformation ratio for the base current I'B of winding 2.

## Matching

### Principle

The currents in windings 1 and 2 cannot be compared directly due to the transformation ratio and the phase displacement introduced by the power transformer.

Sepam™ does not use matching CTs. It uses the rated power and winding voltage data to calculate the transformation ratio and, therefore, to match current amplitude. The vector shift is used to match the phase currents.

### Winding 1 Current Matching

Winding 1 is always matched in the same way, whatever the vector shift of the transformer. The matching is made by clearing the zero-sequence current in order to make the protection function immune to external ground faults.

$$\vec{I}1m = \frac{\vec{I}a}{I_N1} - \frac{\vec{I}a + \vec{I}b + \vec{I}c}{3I_N1}$$

$$\vec{I}2m = \frac{\vec{I}2}{I_N1} - \frac{\vec{I}a + \vec{I}b + \vec{I}c}{3I_N1}$$

$$\vec{I}3m = \frac{\vec{I}c}{I_N1} - \frac{\vec{I}a + \vec{I}b + \vec{I}c}{3I_N1}$$

### Winding 2 Current Matching and Vector Shift

The matching of winding 2 affects the amplitude and phase and takes account of the vector shift of the transformer.

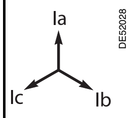
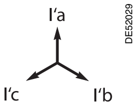
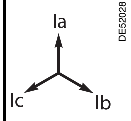
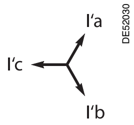
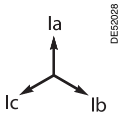
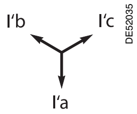
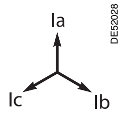
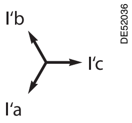
Standard IEC 60076-1 assumes the vector shift is given for a transformer connected to a power source with a phase-rotation sequence of a-b-c. Sepam™ uses this vector shift value for both a-b-c and a-c-b type networks.

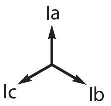
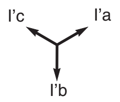
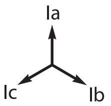
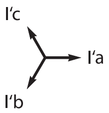
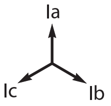
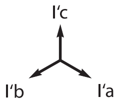
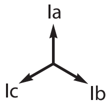
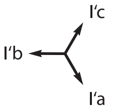
Therefore, it is unnecessary to complement this value by a-b for an a-c-b type network. When the current transformer connections are correct. The vector shift matching is the result of the phase-displacement measurement taken by Sepam™ between the currents in winding 1 and winding 2, divided by 30°.

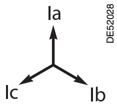
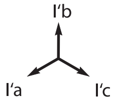
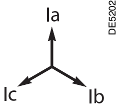
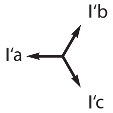
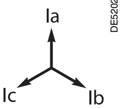
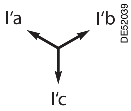
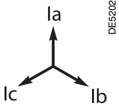
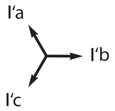
The table on the next page contains vectorial diagrams and matching formulae based on the vector shift of the transformer for networks with type a-b-c phase-rotation sequences.

# Transformer Differential
ANSI Code 87T

### Calculating Matched Currents for Winding 2

| Vector shift | Winding 1 | Winding 2 | Matching |
|---|---|---|---|
| **0** |  Ia<br>Ic<br>Ib<br>DE52028 |  I'a<br>I'c<br>I'b<br>DE52029 | $\frac{\vec{I}'a}{I_{N2}} - \frac{\vec{I}'a + \vec{I}'b -}{3I_{N2}}$<br>$\frac{\vec{I}'b}{I_{N2}} - \frac{\vec{I}'a + \vec{I}'b -}{3I_{N2}}$<br>$\frac{\vec{I}'c}{I_{N2}} - \frac{\vec{I}'a + \vec{I}'b -}{3I_{N2}}$ |
| **1** |  Ia<br>Ic<br>Ib<br>DE52028 |  I'a<br>I'c<br>I'b<br>DE52030 | $\vec{I}'am = \frac{\vec{I}'a - \vec{I}'b}{\sqrt{3}I_{N2}}$<br>$\vec{I}'bm = \frac{\vec{I}'b - \vec{I}'c}{\sqrt{3}I_{N2}}$<br>$\vec{I}'cm = \frac{\vec{I}'c - \vec{I}'a}{\sqrt{3}I_{N2}}$ |
| **6** |  Ia<br>Ic<br>Ib<br>DE52028 |  I'b<br>I'c<br>I'a<br>DE52035 | $am = -\frac{\vec{I}'a}{I_{N2}} + \frac{\vec{I}'a + \vec{I}'b + \vec{I}'c}{3I_{N2}}$<br>$bm = -\frac{\vec{I}'b}{I_{N2}} + \frac{\vec{I}'a + \vec{I}'b + \vec{I}'c}{3I_{N2}}$<br>$\vec{I}'cm = -\frac{\vec{I}'c}{I_{N2}} + \frac{\vec{I}'a + \vec{I}'b + \vec{I}'c}{3I_{N2}}$ |
| **7** |  Ia<br>Ic<br>Ib<br>DE52028 |  I'b<br>I'c<br>I'a<br>DE52036 | $\vec{I}'am = \frac{\vec{I}'b - \vec{I}'a}{\sqrt{3}I_{N2}}$<br>$\vec{I}'bm = \frac{\vec{I}'c - \vec{I}'b}{\sqrt{3}I_{N2}}$<br>$\vec{I}'cm = \frac{\vec{I}'a - \vec{I}'c}{\sqrt{3}I_{N2}}$ |

|  |  |  |  |
|---|---|---|---|
|  |  Ia<br>Ic<br>Ib<br>DE52028 |  I'c<br>I'a<br>I'b<br>DE52031 | $-\frac{\vec{I'}b}{IN2}+\frac{\vec{I'}a+\vec{I'}b}{3IN}$ |
| 3 |  Ia<br>Ic<br>Ib<br>DE52028 |  I'c<br>I'a<br>I'b<br>DE52032 | $\vec{I'}am = \frac{\vec{I'}c-\vec{I'}b}{\sqrt{3}IN2}$<br>$\vec{I'}bm = \frac{\vec{I'}a-\vec{I'}c}{\sqrt{3}IN2}$<br>$\vec{I'}cm = \frac{\vec{I'}b-\vec{I'}a}{\sqrt{3}IN2}$ |
| 2 |  |  | $\frac{\vec{I'}c}{IN2}+\frac{\vec{I'}a+\vec{I'}b}{3IN}$ |
|  |  Ia<br>Ic<br>Ib<br>DE52028 |  I'c<br>I'b<br>I'a<br>DE52033 | $\frac{\vec{I'}c}{IN2}-\frac{\vec{I'}a+\vec{I'}b}{3IN2}$ |
| 4 |  |  | $-\frac{\vec{I'}a}{IN2}+\frac{\vec{I'}a+\vec{I'}b}{3IN}$<br>$\vec{I'}bm = \frac{\vec{I'}a}{IN2}-\frac{\vec{I'}a+\vec{I'}b+\vec{I'}c}{3IN2}$ |
|  |  |  | $\frac{\vec{I'}b}{IN2}-\frac{\vec{I'}a+\vec{I'}b}{3IN2}$ |
| 5 |  Ia<br>Ic<br>Ib<br>DE52028 |  I'c<br>I'b<br>I'a<br>DE52034 | $\vec{I'}am = \frac{\vec{I'}c-\vec{I'}a}{\sqrt{3}IN2}$<br>$\vec{I'}bm = \frac{\vec{I'}a-\vec{I'}b}{\sqrt{3}IN2}$<br>$\vec{I'}cm = \frac{\vec{I'}b-\vec{I'}c}{\sqrt{3}IN2}$ |

|  |  |  |  |
|---|---|---|---|
|  |  Ia<br>Ic<br>Ib<br>DE52028 |  I'b<br>I'a<br>I'c<br>DE52037 | $am = \frac{\vec{I'}b}{IN2}-\frac{\vec{I'}a+\vec{I'}b+\vec{I'}c}{3IN2}$ |
| 9 |  Ia<br>Ic<br>Ib<br>DE52028 |  I'b<br>I'a<br>I'c<br>DE52038 | $\vec{I'}am = \frac{\vec{I'}b-\vec{I'}c}{\sqrt{3}IN2}$<br>$\vec{I'}bm = \frac{\vec{I'}c-\vec{I'}a}{\sqrt{3}IN2}$<br>$\vec{I'}cm = \frac{\vec{I'}a-\vec{I'}b}{\sqrt{3}IN2}$ |
| 8 |  |  | $bm = \frac{\vec{I'}c}{IN2}-\frac{\vec{I'}a+\vec{I'}b+\vec{I'}c}{3IN2}$ |
|  |  Ia<br>Ic<br>Ib<br>DE52028 |  I'a<br>I'b<br>I'c<br>DE52039 | $am = -\frac{\vec{I'}c}{IN2}+\frac{\vec{I'}a+\vec{I'}b+\vec{I'}c}{3IN2}$ |
| 10 |  |  | $cm = \frac{\vec{I'}a}{IN2}-\frac{\vec{I'}a+\vec{I'}b+\vec{I'}c}{3IN2}$ |
|  |  |  | $bm = -\frac{\vec{I'}a}{IN2}+\frac{\vec{I'}a+\vec{I'}b+\vec{I'}c}{3IN2}$<br>$\vec{I'}cm = -\frac{\vec{I'}b}{IN2}+\frac{\vec{I'}a+\vec{I'}b+\vec{I'}c}{3IN2}$ |
| 11 |  Ia<br>Ic<br>Ib<br>DE52028 |  I'a<br>I'b<br>I'c<br>DE52040 | $\vec{I'}am = \frac{\vec{I'}a-\vec{I'}c}{\sqrt{3}IN2}$<br>$\vec{I'}bm = \frac{\vec{I'}b-\vec{I'}a}{\sqrt{3}IN2}$<br>$\vec{I'}cm = \frac{\vec{I'}c-\vec{I'}b}{\sqrt{3}IN2}$ |

## Test Mode

Two operating modes facilitate maintenance and startup operations:

- *normal mode*: the protection function controls the tripping and indication outputs based on the settings. This is the standard operating mode
- *test mode*: the protection function controls tripping and indication outputs based on test mode settings. This mode is accessed only by the SFT2841 software, once it is connected and the Protection setting password entered. The system returns to normal mode when the software is disconnected

***Note : Transfer from normal mode to test mode can result in nuisance tripping if the protected transformer is energized.***

Test mode settings:

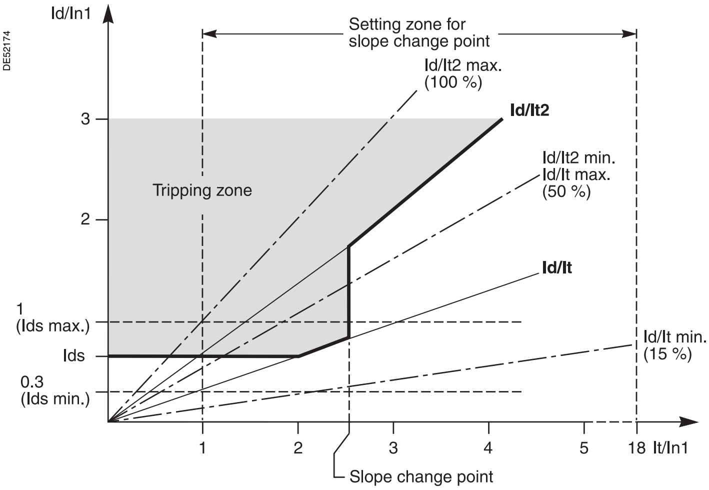
- $V_{LLN1} = \frac{S}{I_N \times 3}$
- $V_{LLN2} = \frac{S}{I'_N \times 3}$
- vector shift = 0

# Transformer Differential
ANSI Code 87T

## High Set Point
A non-restrained differential current set point will ensure fast tripping in the event of significant fault currents. This threshold must be set to a value higher than that of the inrush current.

## Percentage-Based Curve
The percentage-based curve is made up of the following:
- a low set point (Ids)
- two straight lines crossing zero and with adjustable slopes (Id/It and Id/It2)
- the slope change point.

The curve must be set to protect itself against current-transformer measurement errors and transformation errors attributable to the tap changer. Also, the protection function must be immune to power shunts on auxiliary windings.



## Self-Adaptive Restraint
The self-adaptive restraint is particularly suitable for transformers, where:

$$\hat{I}inr < \frac{8}{2}\hat{I}2_{N} = 8I_{N}$$

where **Îinr** is the peak tripping current
**Î$_N$** is the rated peak current
**I$_N$** is the rated transformer current

This neutral network restraint ensures stability in the event of an external fault by analyzing the second- and fifth-harmonic factors, the differential currents and the through currents. It ensures stability in the event of the following:
- transformer closing
- an asymmetrical fault outside the zone that saturates the CTs
- the transformer operating on a voltage supply that is too high (overexcitation).

Detecting the presence of harmonics and monitoring the through and differential currents, the restraint automatically increases the low set point and the percentage-based slopes. It is also more sensitive than the high set point.

Using the high set point is unecesseary when this restraint is active. Also, as the restraint integrates the stabilization slope for high through currents (which can saturate the CTs), slope Id/It2 does not have to be activated.

## Conventional Restraint
The conventional restraint comprises a second-harmonic set point for each phase and a fifth-harmonic set point for each phase.

The second-harmonic set point ensures that the protection function will not pick up if the transformer closes or the CTs become saturated. The restraint can be global (cross-blocking: all three phases are restrained as soon as the harmonic in one phase exceeds the set point) or phase-specific (no cross-blocking: only the phase with a harmonic exceeding the set point is restrained). Cross-blocking is recommended for transformers used in three-phase mode.

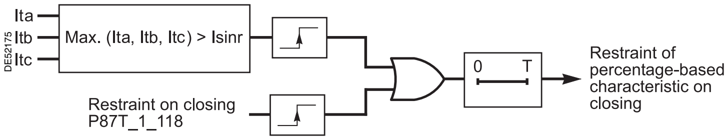
The fifth-harmonic set point ensures that the protection function will not pick up if the transformer is connected to a voltage supply that is too high. The restraint can be global (all three phases are restrained) or phase-specific (only the phase with a harmonic exceeding the set point is restrained). Restraint without cross-blocking is recommended for normal operation.

## Restraint on Closing

In some cases, the harmonic content of the transformer inrush current is not sufficient to activate harmonic restraints. An additional restraint can be activated:

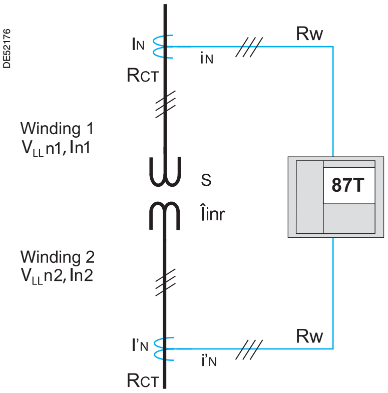
- when the through current exceeds an adjustable set point Isinr
- by an internal variable, P87T_1_118, controlled by logic equations or Logipam.

This restraint is applied to the percentage-based differential elements for an adjustable time period T. It is not applied to the high set point.


DE52175
Ita
Itb
Itc
Max. (Ita, Itb, Itc) > Isinr
Restraint on closing
P87T_1_118
0
T
Restraint of percentage-based characteristic on closing

## Restraint on CT Loss

CT loss can distort the differential current and cause nuisance tripping. This restraint detects a measurement dropping to zero abnormally by analyzing sampled differential and through currents.


DE52176
IN
iN
Rw
RCT
Winding 1
VLLn1, In1
S
Îinr
87T
Winding 2
VLLn2, In2
I'N
i'N
Rw
RCT

## Sizing Phase-Current Transformers

The primary rated current of the current transformers is governed by the following rule:

- for winding 1: $\mathbf{0.1} \times \frac{\mathbf{S}}{\mathbf{V_{LLn1}} \times 3} \text{ y } \mathbf{I_N} \text{ y } \mathbf{2.5} \times \frac{\mathbf{S}}{\mathbf{V_{LLn1}} \times 3}$
- for winding 2: $\mathbf{0.1} \times \frac{\mathbf{S}}{\mathbf{V_{LLn2}} \times 3} \text{ y } \mathbf{I'_N} \text{ y } \mathbf{2.5} \times \frac{\mathbf{S}}{\mathbf{V_{LLn2}} \times 3}$

where:

**IN** is the primary rated current of the CT.
**iN** is the secondary rated current of the CT.
**RCT** is the internal resistance of the CT.
**Rw** is the resistance of the wiring and the CT load.

# Transformer Differential
## ANSI Code 87T

### Characteristics

| | | |
|---|---|---|
| **Settings** | | |
| **Low Set Point Ids** | | |
| Setting range | | 30% to 100% of IN1 |
| Accuracy (1) | | ±2% |
| Resolution | | 1% |
| Drop-out/pick-up ratio | | 93.5% ±5% |
| **Percentage-Based Characteristic Id/It** | | |
| Setting range | | 15% to 50% |
| Accuracy (1) | | ±2% |
| Resolution | | 1% |
| Drop-out/pick-up ratio | | 93.5% ±5% |
| **Percentage-Based Characteristic Id/It2** | | |
| Setting range | | None, 50% to 100% |
| Accuracy (1) | | ±2% |
| Resolution | | 1% |
| Drop-out/pick-up ratio | | 93.5% ±5% |
| **Slope Change Point** | | |
| Setting range | | None, IN1 to 18 IN1 |
| Accuracy (1) | | ±5% |
| Resolution | | 0.1 INa |
| Drop-out/pick-up ratio | | 93.5% ±5% |
| **Test Mode** | | |
| Setting range | | Active/Not active |
| **Advanced Settings** | | |
| Selection of restraint | | Conventional/Self-adaptive |
| **Restraint on CT Loss** | | |
| Setting range | | Active/Not active |
| **Restraint on Closing** | | |
| Setting range | | Active/Not active |
| Magnetization current set point Isinr | Setting range | 1% to 10% |
| | Accuracy (1) | ±5% |
| | Resolution | 1% |
| | Drop-out/pick-up ratio | 90% ±5% or 0.5% IN1 |
| Time delay | Setting range | 0 to 300 s |
| | Accuracy (1) | ±2% or -10 ms to +25 ms |
| | Resolution | 10 ms |
| **High Set Point Idmax** | | |
| Setting range | Conventional restraint | 3 to 18 IN1 |
| | Self-adaptive restraint | None, 3 to 18 IN1 |
| Accuracy (1) | | ±2% |
| Resolution | | 1% |
| Drop-out/pick-up ratio | | 93.5% ±5% |
| **Second-Harmonic Set Point for Conventional Restraint** | | |
| Setting range | | None, 5 to 40% |
| Accuracy (1) | | ±5% |
| Resolution | | 1% |
| Drop-out/pick-up ratio | | 90% ±5% |
| **Second-Harmonic Restraint for Conventional Restraint** | | |
| Setting range | | Phase-specific/Global |
| **Fifth-Harmonic Set Point for Conventional Restraint** | | |
| Setting range | | None, 5 to 40% |
| Accuracy (1) | | ±5% |
| Resolution | | 1% |
| Drop-out/pick-up ratio | | 90% ±5% |
| **Fifth-Harmonic Restraint for Conventional Restraint** | | |
| Setting range | | Phase-specific/Global |
| **Characteristic Times** | | |
| Operating time high set point | | < 45 ms at 2 Id |
| Operating time percentage-based curve | | < 45 ms at 2 Id |
| Reset time | | < 45 ms at 2 Id |

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Protection reset | P87T_1_101 | ■ | ■ |
| Protection blocking | P87T_1_113 | ■ | ■ |
| Restraint on closing | P87T_1_118 | ■ | ■ |

**Outputs**

| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Protection output | P87T_1_3 | ■ | ■ | ■ |
| Protection blocked | P87T_1_16 | ■ | ■ | - |
| High set point | P87T_1_33 | ■ | ■ | - |
| Percentage-based threshold | P87T_1_34 | ■ | ■ | - |
| CT loss | P87T_1_39 | ■ | ■ | - |
| Test mode | P87T_1_41 | ■ | ■ | - |

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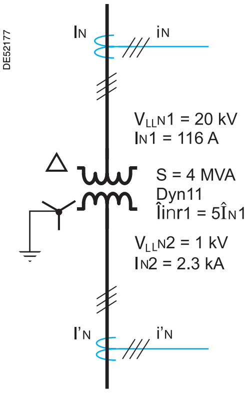
*__(1)__ Under reference conditions (IEC 60255-6).*

# **Transformer Differential**
ANSI Code 87T



## Example 1

4 MVA, Dyn11, 20 kV/1 kV transformer, the peak closing current is: $\hat{I}_{inr} = 5\hat{I}_N$

The transformer operates normally at its rated load, but will tolerate operation at up to 120% of its rated power.

**Sensor selection**
The rated current of the windings is:

$$I_{N1} = \frac{S}{3V_{LLN1}} = \frac{4\ MVA}{320\ kV} = 116\ A \quad \text{and} \quad I_{N2} = \frac{S}{3V_{LLN2}} = \frac{4\ MVA}{31\ kV} = 2.3\ kA$$

The CTs can support an overload of 120%:
**$I_N > 116\ A \times 1.2 = 139.2\ A$** and **$I'n > 2.3\ kA \times 1.2 = 2.76\ kA$**

The main currents of the CTs must also meet the following requirements:

$$0.1\frac{S}{3V_{LLN1}}\ y\ I_n\ y\ 2.5\frac{S}{3V_{LLN1}} \quad \text{and} \quad 0.1\frac{S}{3V_{LLN2}}\ y\ I'_n\ y\ 2.5\frac{S}{3V_{LLN2}}$$

So, for this transformer:

**$11.6\ A \le I_N \le 290\ A$** and **$230\ A \le I'_N \le 5.75\ kA$**

Taking these two restrictions into account, the values selected are those standardized by ANSI:

**$I_N = 150\ A$** and **$I'_N = 3\ kA$**

The tripping current is $\hat{I}_{inr} = 5\hat{I}_N$, so, for both winding 1 and winding 2:

$$\hat{I}_{inr1} = 5 \times 2 \times 116\ A = 820\ A$$

$$\hat{I}_{inr2} = 5 \times 2 \times 2.3\ kA = 16.3\ kA$$

These tripping currents must be compared with the rated current of the current sensors in order to select the accuracy limit factor:

$$\frac{\hat{I}_{inr1}}{2I_N} = \frac{820\ A}{2 \times 150\ A} = 3.9 < 6.7 \quad \text{and} \quad \frac{\hat{I}_{inr2}}{2I'_N} = \frac{16.3\ kA}{2 \times 3\ kA} = 3.8 < 6.7$$

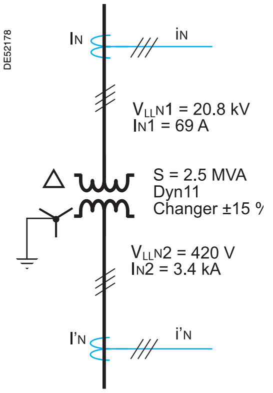
The accuracy limit factor is, therefore, 20, with a rated burden of:
**$VA_{CT} \ge Rw.i_N^2$**.

The following sensors are selected:
- for winding 1: 150 A/1 A, 5P20 where $VA_{CT1}$
- for winding 2: 3 kA/1 A, 5P20 where $VA_{CT2}$.

**Setting the Percentage-based Curve and the Maximum Threshold**
As this transformer does not feature a tap changer or an auxiliary winding, the tripping threshold is, therefore, set to a minimum value (Ids = 30%) and the slope to Id/It = 15%.

As the ratio between the closing current and the rated current is less than $8/\sqrt{2}$, the self-adaptive harmonic restraint is selected. The second slope on the percentage-based curve and the maximum threshold are not necessary and are not, therefore, used.

# Transformer Differential
Code ANSI 87T



## Example 2

2.5 MVA, Dyn11, 20.8 kV/420 V transformer, the peak closing current is:

$\hat{I}_{inr} = 9.6\,\hat{I}_N$

The transformer features a tap changer with a tap range of ±15% of the rated voltage of winding 2.

### Sensor selection

The rated current of the windings is:

$$I_{N1} = \frac{S}{3V_{LLn1}} = \frac{2.5\ MVA}{3\,20.8\ kV} = 69\ A \quad \text{and} \quad I_{N2} = \frac{S}{3V_{LLn2}} = \frac{2.5\ MVA}{3\,420\ V} = 3.4\ kA$$

Thanks to the tap changer, the current sensors can support an overload of 115%:

**$I_N > 69\ A \times 1.15 = 79.4\ A$ and $I'_N > 3.4\ kA \times 1.15 = 3.91\ kA$**

The main currents of the CTs must also meet the following requirements:

$$0.1\frac{S}{3V_{LLn1}}\ y\ I_N\ y\ 2.5\frac{S}{3V_{LLn1}} \qquad \text{and} \quad 0.1\frac{S}{3V_{LLn2}}\ y\ I'_N\ y\ 2.5\frac{S}{3V_{LLn2}}$$

So, for this transformer:

**$6.9\ A \le I_N \le 173\ A$ and $340\ A \le I'_N \le 8.5\ kA$**

Taking these two restrictions into account, the values selected are those standardized by the IEC:

**In = 100 A and I'n = 4 kA**

The tripping current is $\hat{I}_{inr} = 9{,}6\,\hat{I}_N$, so, for both winding 1 and winding 2:

$$\hat{I}_{inr1} = 9.6 \times 2 \times 69\ A = 937\ A$$

$$\hat{I}_{inr2} = 9.6 \times 2 \times 3.4\ kA = 46.2\ kA$$

These tripping currents must be compared with the rated current of the CTs in order to select the accuracy limit factor:

$$\frac{\hat{I}_{inr1}}{2I_N} = \frac{937\ A}{2 \times 100\ A} = 6.6 < 6.7 \quad \text{and} \quad \frac{\hat{I}_{inr2}}{2I'_N} = \frac{46.2\ kA}{2 \times 4\ kA} = 8.2 > 6.7$$

The accuracy limit factor is, therefore, 20 for the sensors in winding 1

and equal to $3\frac{\hat{I}_{inr2}}{2I'_N} = 3\frac{46.2\ kA}{2 \times 4\ kA} = 24.5$ for winding 2.

The closest standard value, 30, is selected.

The following sensors are selected:

- for winding 1: 100 A/1A, 5P20
- for winding 2: 4 kA/1A, 5P30.

### Setting the Percentage-Based Curve and the Maximum Threshold

This transformer features a tap changer. The continuous differential current due to the voltage variation of the tap changer is:

$$Idchanger = \frac{x}{1 - x} \times 100\%$$

where x is the maximum variation of the tap changer. In this example, x = 0.15.

The differential current due to the change in the transformation ratio is:

$$Idchanger = \frac{0.15}{1 - 0.15} \times 100\% = 17.6\%$$

Type 5P sensors with a maximum measurement error tolerance of 10% are used.
The measurement accuracy of the relay is ±1% for Ids and Id/It.
The minimum setting is, therefore:

**Ids = IdChanger + IdMeasure + IdRelay + margin**.

Assuming a margin of approximately 5%, the minimum setting is, therefore:

**$Ids = 17.6 + 10 + 1 + 5 \approx 34\%$**

Ids and the Id/It slope are set to 34%.

The ratio between the closing current and the rated current is 9.6. As this ratio is greater than $8/\sqrt{2}$, the conventional harmonic restraint is selected.

The second slope on the percentage-based curve is set to 70%, starting at 6 In1 in order to ensure sufficient stability of the protection fault in the event of external faults.

The high set point is set to a value higher than that of the closing current with the following margin:

$$Idmax = 2 \times \frac{\hat{I}_{NR}}{\hat{I}_N} = 2 \times 9.6\ In1 = 13.6\ In1$$

The conventional harmonic restraint is set with:

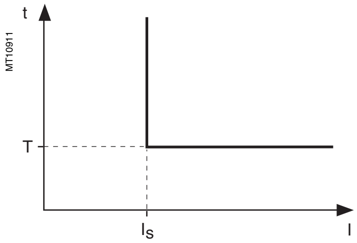
- a second-harmonic set point equal to 20%, with cross-blocking
- a fifth-harmonic set point equal to 25%, without cross-blocking.

# General
## Trip Curves

*Presentation of tripping curve operation and settings for protection functions using:*
- *definite time*
- *IDMT*
- *timer hold.*

### Definite Time Protection

The tripping time is constant. The time delay is started when the set point is overrun.



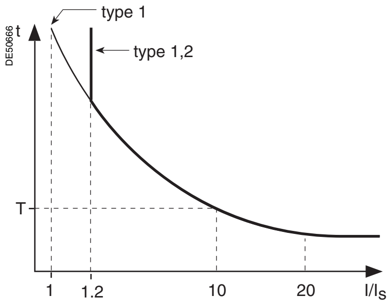
*Definite time protection principle*

### IDMT Protection

The operation time depends on the protected value (phase current, ground fault current, etc.) in accordance with standards IEC 60255-3, BS 142 and IEEE C-37112. Operation is represented by a characteristic curve, e.g.:
- t = f(I) curve for the **phase overcurrent** function
- t = f(Ir) curve for the **ground fault** function.

The rest of the document is based on t = f(I); the reasoning may be extended to other variables Ir, etc.
The curve is defined by:
- its type (standard inverse, very inverse, extremely inverse, etc.)
- current setting Is which corresponds to the vertical asymptote of the curve
- time delay T which corresponds to the operation time for I = 10 Is

These three settings are made in order of type, Is current, and time delay T.
Changing the time delay T setting by x% changes all of the operation times in the curve by x%.



*IDMT protection principle*

The tripping time for I/Is values less than 1.2 depends on the type of curve selected.

| Name of Curve | Type |
|---|---|
| Standard inverse time (SIT) | 1.2 |
| Very inverse time (VIT or LTI) | 1.2 |
| Extremely inverse time (EIT) | 1.2 |
| Ultra inverse time (UIT) | 1.2 |
| RI curve | 1 |
| IEC inverse time SIT / A | 1 |
| IEC very inverse time VIT or LTI / B | 1 |
| IEC extremely inverse time EIT / C | 1 |
| IEEE moderately inverse (IEC / D) | 1 |
| IEEE very inverse (IEC / E) | 1 |
| IEEE extremely inverse (IEC / F) | 1 |
| IAC inverse | 1 |
| IAC very inverse | 1 |
| IAC extremely inverse | 1 |

- when the monitored value is more than 20 times the set point, the tripping time is limited to the value corresponding to 20 times the set point.
- if the monitored value exceeds the measurement capacity of Sepam™ (40 IN for the phase current channels, 20 INr for the residual current channels), the tripping time is limited to the value corresponding to the largest measurable value (40 IN or 20 INr).

# General
## Trip Curves

### Current IDMT Tripping Curves

Multiple IDMT tripping curves are offered, to cover most applications:

- IEC curves (SIT, VIT/LTI, EIT)
- IEEE curves (MI, VI, EI)
- commonly used curves (UIT, RI, IAC).

**IEC Curves**

**Equation**

$$t_d(I) = \frac{k}{\left(\frac{I}{I_s}\right)^{\alpha} - 1} \times \frac{T}{\beta}$$

| Curve Type | Coefficient Values | | |
|---|---|---|---|
| | k | α | β |
| Standard inverse / A | 0.14 | 0.02 | 2.97 |
| Very inverse / B | 13.5 | 1 | 1.50 |
| Long time inverse / B | 120 | 1 | 13.33 |
| Extremely inverse / C | 80 | 2 | 0.808 |
| Ultra inverse | 315.2 | 2.5 | 1 |

**RI curve**

Equation:

$$t_d(I) = \frac{1}{0.339 - 0.236\left(\frac{I}{I_s}\right)^{-1}} \times \frac{T}{3.1706}$$

**IEEE Curves**

**Equation**

$$t_d(I) = \left(\frac{A}{\left(\frac{I}{I_s}\right)^{p} - 1} + B\right) \times \frac{T}{\beta}$$

| Curve Type | Coefficient Values | | | |
|---|---|---|---|---|
| | A | B | p | β |
| Moderately inverse | 0.010 | 0.023 | 0.02 | 0.241 |
| Very inverse | 3.922 | 0.098 | 2 | 0.138 |
| Extremely inverse | 5.64 | 0.0243 | 2 | 0.081 |

**IAC Curves**

**Equation**

$$t_d(I) = \left(A + \frac{B}{\left(\frac{I}{I_s} - C\right)} + \frac{D}{\left(\frac{I}{I_s} - C\right)^2} + \frac{E}{\left(\frac{I}{I_s} - C\right)^3}\right) x \frac{T}{\beta}$$

| Curve Type | Coefficient Values | | | | | |
|---|---|---|---|---|---|---|
| | A | B | C | D | E | β |
| Inverse | 0.208 | 0.863 | 0.800 | -0.418 | 0.195 | 0.297 |
| Very inverse | 0.090 | 0.795 | 0.100 | -1.288 | 7.958 | 0.165 |
| Extremely inverse | 0.004 | 0.638 | 0.620 | 1.787 | 0.246 | 0.092 |

### Voltage IDMT Tripping Curves

**Equation for ANSI 27 - Undervoltage**

$$t_d(V) = \frac{T}{1 - \left(\frac{V}{V_s}\right)}$$

**Equation for ANSI 59N - Neutral Voltage Displacement**

$$t_d(V) = \frac{T}{\left(\frac{V}{V_S}\right) - 1}$$

### Voltage/Frequency Ratio IDMT Tripping Curves

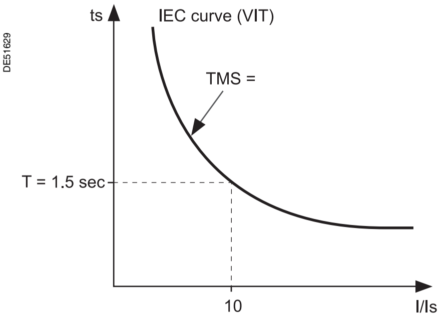
**Equation for ANSI 24 - Overexcitation (V/Hz)**

Where G = $V_{Ln}$/f or $V_{LL}$/f

| CurveType | p |
|---|---|
| A | 0.5 |

| | |
|---|---|
| B | 1 |
| C | 2 |

$$t_d(G) = \frac{1}{\left(\frac{G}{G_s} - 1\right)^p} \text{ x } T$$



*Example.*

## Setting IDMT Tripping Curves, Time Delay T or TMS Factor

The time delays of current IDMT tripping curves (except for customized and RI curves) may be set as follows:

- time T, operating time at 10 x Is
- TMS factor, factor shown as T/β in the equations on the left.

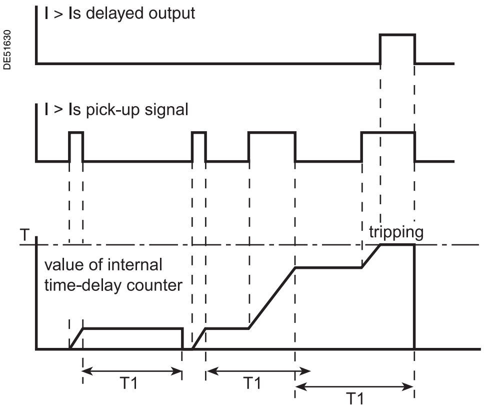
Example: $\mathbf{t(I)} = \frac{13.5}{\frac{I}{Is}-1} \times \mathbf{TMS}$ where $\mathbf{TMS} = \frac{T}{1.5}$.

The IEC curve of the VIT type is positioned so as to be the same with TMS = 1 or T = 1.5 s.

## TMS Setting Mode

Retrofit Sepam™ to electromechanical relay may be done as the following example shows. With a U.S. built VIT relay having #3 TDS, 4A Tap, 500:5A CT, use a primary current setting of 4A x 500/5 = 400A with an IEEE VIT curve set on TMS#3. To verify coordination, plot the associated equation with T/β replaced by TMS value and all coefficients inserted. Another method takes the plotted family (IEEE VIT) of curves and transposes them by a factor of β.

## Timer Hold



*Detection of restriking faults with adjustable timer hold.*

The adjustable timer hold T1 is used for:

- detection of restriking faults (DT curve)
- coordination with electromechanical relays (IDMT curve).
- Timer hold may be blocked if necessary.

### Equation for IDMT Timer Hold Curve

Equation: $\mathbf{t_r(I)} = \frac{T1}{1-\left(\frac{I}{Is}\right)^2} \times \frac{T}{\beta}$ where $\frac{T}{\beta} = \mathbf{TMS}$.

T1 = timer hold setting (timer hold for I reset = 0 and TMS = 1)
T = tripping time delay setting (at 10 Is)

β = basic tripping curve value at $\frac{k}{10^{\alpha}-1}$.

DE50755

*Timer hold dependent on current I.*

DE50754

*Constant timer hold.*

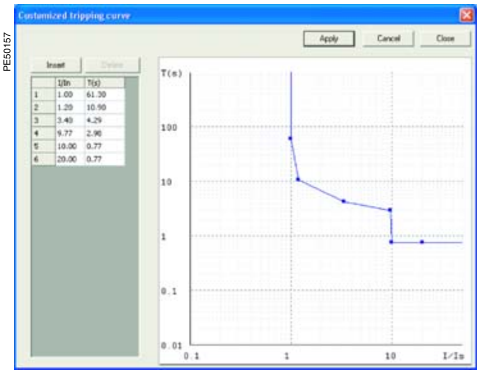
## Customized Tripping Curve

Defined point by point using the SFT2841 setting and operating software tool (application menu), this curve may be used to solve all special cases involving protection coordination or installation renovation.

It offers between 2 and 30 points whose coordinates must be:

- increasing on the I/Is axis
- decreasing on the t axis.

The two end points define the curve asymptotes. There must be at least one point on the horizontal coordinate 10 I/Is to serve as a reference point to set the function time delay by curve shifting.



|  | I/In | T(s) |
|---|---|---|
| 1 | 1.00 | 61.30 |
| 2 | 1.20 | 10.90 |
| 3 | 3.40 | 4.29 |
| 4 | 9.77 | 2.90 |
| 5 | 10.00 | 0.77 |
| 6 | 20.00 | 0.77 |

*Customized tripping curve set using SFT2841 software.*

## Implementing IDMT curves: examples of problems to be solved.

**Problem 1.**
Given the type of IDMT, determine the Is current and time delay T settings.

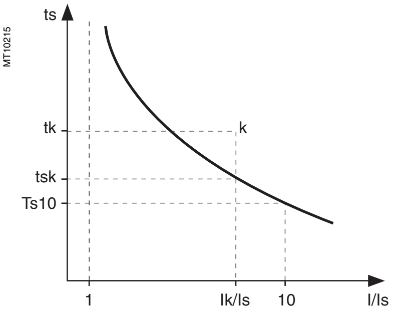
Theoretically, the Is current setting corresponds to the maximum continuous current. It is generally the rated current of the protected equipment (cable, transformer). The time delay T corresponds to operation at 10 Is on the curve. This setting is determined by factoring the constraints involved in discrimination with the upstream and downstream protection devices.

The discrimination constraint leads to the definition of point A on the operation curve (IA, tA), like the point that corresponds to the maximum fault current for the downstream protection device.

**Problem 2.**
Given the type of IDMT, the Is current setting and a point k (Ik, tk) on the operation curve, determine the time delay setting T.
On the standard curve of the same type, read the operation time tsk that corresponds to the relative current **Ik/Is** and the operation time Ts10 that corresponds to the relative current **I/Is = 10.**

The time delay setting to be used so that the operation curve passes through the point k (Ik, tk) is:

$$T = Ts10 \times \frac{tk}{tsk}$$

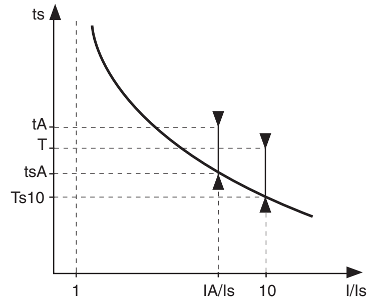


**Another practical method:**
the table below gives the values of **K = ts/ts10** as a function of **I/Is.**
In the column that corresponds to the type of time delay, read the value **K = tsk/Ts10** on the line for **Ik/Is.**
The time delay setting to be used so that the operation curve passes through point k (Ik, tk) is: **T = tk/k.**

**Example**
Data:
- type of time delay: standard inverse time (**SIT**)
- set point: Is
- a point k on the operation curve: k (3.5 Is; 4 s)

**Question:** What is the time delay T setting (operation time at 10 Is)?
Reading the table: **SIT** column, line **I/Is** = **3.5** therefore **K = 1.858**
**Answer:** The time delay setting is **T = 4/1.858 = 2.15 s**

**Problem 3.**
Given the Is current and time delay T settings for a type of time delay (standard inverse, very inverse, extremely inverse), find the operation time for a current value IA. On the standard curve of the same type, read the operation time tsA that corresponds to the relative current IA/Is and the operation time Ts10 that corresponds to the relative current **I/Is = 10.**
The operation time tA for the current IA with the Is and T settings is **tA = tsA x T/Ts10.**



**Another practical method:**
the table below gives the values of **K = ts/Ts10** as a function of **I/Is.**
In the column that corresponds to the type of time delay, read the value **K = tsA/Ts10** on the line for **IA/Is,** the operation time tA for the current IA with the Is and T settings is **tA = K . T.**

**Example**
Data:

- type of time delay: very inverse time (**VIT**)
- set point: Is
- time delay T = 0.8 s.

**Question:** What is the operation time for the current IA = 6 Is?
Reading the table: **VIT** column**,** line I/Is = 6, therefore k = 1.8

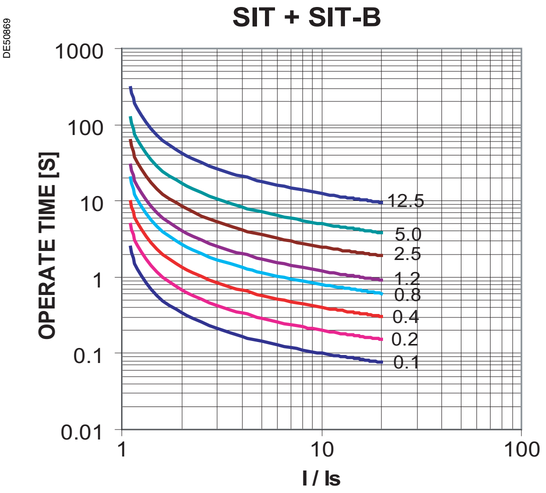
**Answer:** The operation time for the current IA is t = 1.80 x 0.8 = 1.44 s.

## Table of K Values

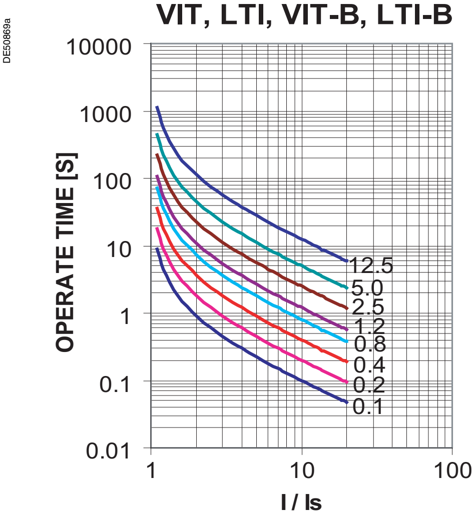
| I/Is | SIT and IEC/A | VIT, LTI and IEC/B | EIT and IEC/C | UIT | RI | IEEE MI (IEC/D) | IEEE VI (IEC/E) | IEEE EI (IEC/F) | IAC I | IAC VI | IAC EI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.0** | — | — | — | — | 3.062 | — | — | — | 62.005 | 62.272 | 200.226 |
| **1.1** | 24.700 (1) | 90.000 (1) | 471.429 (1) | — | 2.534 | 22.461 | 136.228 | 330.606 | 19.033 | 45.678 | 122.172 |
| **1.2** | 12.901 | 45.000 | 225.000 | 545.905 | 2.216 | 11.777 | 65.390 | 157.946 | 9.413 | 34.628 | 82.899 |
| **1.5** | 5.788 | 18.000 | 79.200 | 179.548 | 1.736 | 5.336 | 23.479 | 55.791 | 3.891 | 17.539 | 36.687 |
| **2.0** | 3.376 | 9.000 | 33.000 | 67.691 | 1.427 | 3.152 | 10.199 | 23.421 | 2.524 | 7.932 | 16.178 |
| **2.5** | 2.548 | 6.000 | 18.857 | 35.490 | 1.290 | 2.402 | 6.133 | 13.512 | 2.056 | 4.676 | 9.566 |
| **3.0** | 2.121 | 4.500 | 12.375 | 21.608 | 1.212 | 2.016 | 4.270 | 8.970 | 1.792 | 3.249 | 6.541 |
| **3.5** | 1.858 | 3.600 | 8.800 | 14.382 | 1.161 | 1.777 | 3.242 | 6.465 | 1.617 | 2.509 | 4.872 |
| **4.0** | 1.676 | 3.000 | 6.600 | 10.169 | 1.126 | 1.613 | 2.610 | 4.924 | 1.491 | 2.076 | 3.839 |
| **4.5** | 1.543 | 2.571 | 5.143 | 7.513 | 1.101 | 1.492 | 2.191 | 3.903 | 1.396 | 1.800 | 3.146 |
| **5.0** | 1.441 | 2.250 | 4.125 | 5.742 | 1.081 | 1.399 | 1.898 | 3.190 | 1.321 | 1.610 | 2.653 |
| **5.5** | 1.359 | 2.000 | 3.385 | 4.507 | 1.065 | 1.325 | 1.686 | 2.671 | 1.261 | 1.473 | 2.288 |
| **6.0** | 1.292 | 1.800 | 2.829 | 3.616 | 1.053 | 1.264 | 1.526 | 2.281 | 1.211 | 1.370 | 2.007 |
| **6.5** | 1.236 | 1.636 | 2.400 | 2.954 | 1.042 | 1.213 | 1.402 | 1.981 | 1.170 | 1.289 | 1.786 |
| **7.0** | 1.188 | 1.500 | 2.063 | 2.450 | 1.033 | 1.170 | 1.305 | 1.744 | 1.135 | 1.224 | 1.607 |
| **7.5** | 1.146 | 1.385 | 1.792 | 2.060 | 1.026 | 1.132 | 1.228 | 1.555 | 1.105 | 1.171 | 1.460 |
| **8.0** | 1.110 | 1.286 | 1.571 | 1.751 | 1.019 | 1.099 | 1.164 | 1.400 | 1.078 | 1.126 | 1.337 |
| **8.5** | 1.078 | 1.200 | 1.390 | 1.504 | 1.013 | 1.070 | 1.112 | 1.273 | 1.055 | 1.087 | 1.233 |
| **9.0** | 1.049 | 1.125 | 1.238 | 1.303 | 1.008 | 1.044 | 1.068 | 1.166 | 1.035 | 1.054 | 1.144 |
| **9.5** | 1.023 | 1.059 | 1.109 | 1.137 | 1.004 | 1.021 | 1.031 | 1.077 | 1.016 | 1.026 | 1.067 |
| **10.0** | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| **10.5** | 0.979 | 0.947 | 0.906 | 0.885 | 0.996 | 0.981 | 0.973 | 0.934 | 0.985 | 0.977 | 0.941 |
| **11.0** | 0.959 | 0.900 | 0.825 | 0.787 | 0.993 | 0.963 | 0.950 | 0.877 | 0.972 | 0.957 | 0.888 |
| **11.5** | 0.941 | 0.857 | 0.754 | 0.704 | 0.990 | 0.947 | 0.929 | 0.828 | 0.960 | 0.939 | 0.841 |
| **12.0** | 0.925 | 0.818 | 0.692 | 0.633 | 0.988 | 0.932 | 0.912 | 0.784 | 0.949 | 0.922 | 0.799 |
| **12.5** | 0.910 | 0.783 | 0.638 | 0.572 | 0.985 | 0.918 | 0.896 | 0.746 | 0.938 | 0.907 | 0.761 |
| **13.0** | 0.895 | 0.750 | 0.589 | 0.518 | 0.983 | 0.905 | 0.882 | 0.712 | 0.929 | 0.893 | 0.727 |
| **13.5** | 0.882 | 0.720 | 0.546 | 0.471 | 0.981 | 0.893 | 0.870 | 0.682 | 0.920 | 0.880 | 0.695 |
| **14.0** | 0.870 | 0.692 | 0.508 | 0.430 | 0.979 | 0.882 | 0.858 | 0.655 | 0.912 | 0.868 | 0.667 |
| **14.5** | 0.858 | 0.667 | 0.473 | 0.394 | 0.977 | 0.871 | 0.849 | 0.631 | 0.905 | 0.857 | 0.641 |
| **15.0** | 0.847 | 0.643 | 0.442 | 0.362 | 0.976 | 0.861 | 0.840 | 0.609 | 0.898 | 0.846 | 0.616 |
| **15.5** | 0.836 | 0.621 | 0.414 | 0.334 | 0.974 | 0.852 | 0.831 | 0.589 | 0.891 | 0.837 | 0.594 |
| **16.0** | 0.827 | 0.600 | 0.388 | 0.308 | 0.973 | 0.843 | 0.824 | 0.571 | 0.885 | 0.828 | 0.573 |
| **16.5** | 0.817 | 0.581 | 0.365 | 0.285 | 0.971 | 0.834 | 0.817 | 0.555 | 0.879 | 0.819 | 0.554 |
| **17.0** | 0.808 | 0.563 | 0.344 | 0.265 | 0.970 | 0.826 | 0.811 | 0.540 | 0.874 | 0.811 | 0.536 |
| **17.5** | 0.800 | 0.545 | 0.324 | 0.246 | 0.969 | 0.819 | 0.806 | 0.527 | 0.869 | 0.804 | 0.519 |
| **18.0** | 0.792 | 0.529 | 0.307 | 0.229 | 0.968 | 0.812 | 0.801 | 0.514 | 0.864 | 0.797 | 0.504 |
| **18.5** | 0.784 | 0.514 | 0.290 | 0.214 | 0.967 | 0.805 | 0.796 | 0.503 | 0.860 | 0.790 | 0.489 |
| **19.0** | 0.777 | 0.500 | 0.275 | 0.200 | 0.966 | 0.798 | 0.792 | 0.492 | 0.855 | 0.784 | 0.475 |
| **19.5** | 0.770 | 0.486 | 0.261 | 0.188 | 0.965 | 0.792 | 0.788 | 0.482 | 0.851 | 0.778 | 0.463 |
| **20.0** | 0.763 | 0.474 | 0.248 | 0.176 | 0.964 | 0.786 | 0.784 | 0.473 | 0.848 | 0.772 | 0.450 |

*(1) Values suitable only for IEC A, B and C curves.*

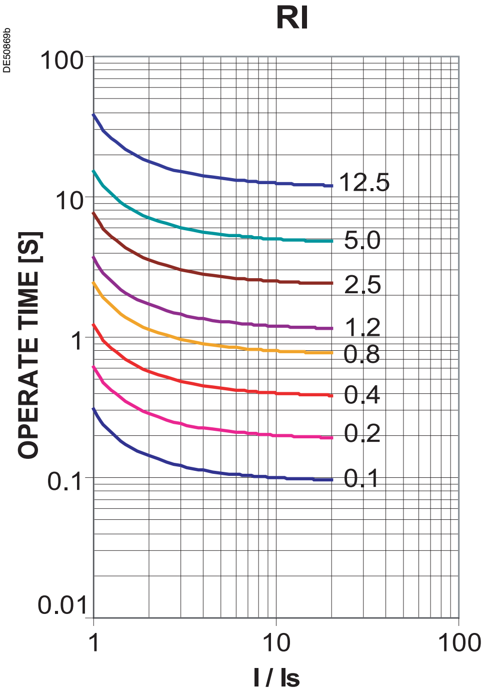
**Standard Inverse Time (SIT) Curve**



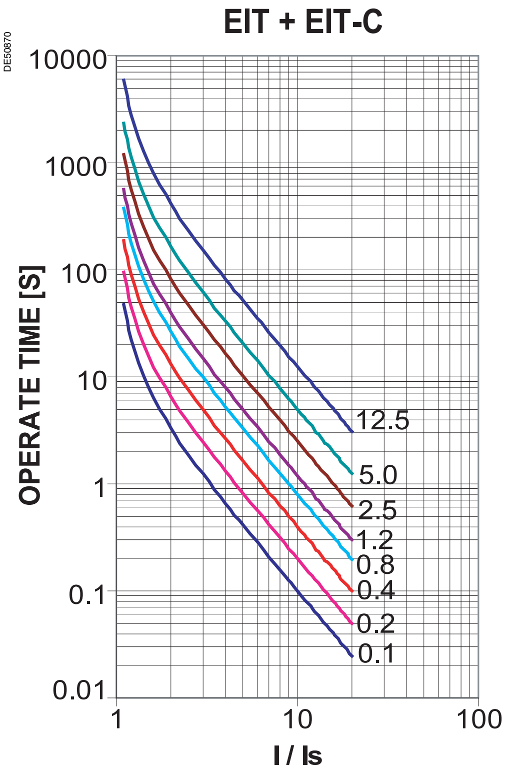
**Very Inverse Time (VIT) or LTI Curve**



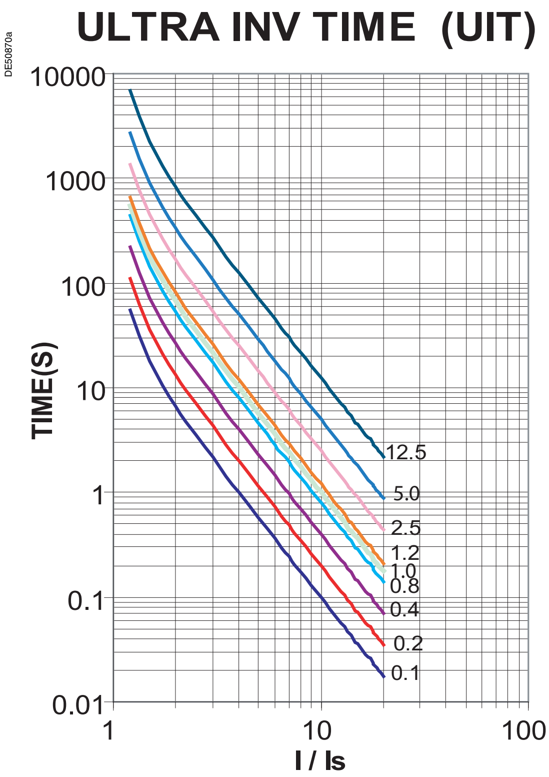
**RI Curve**



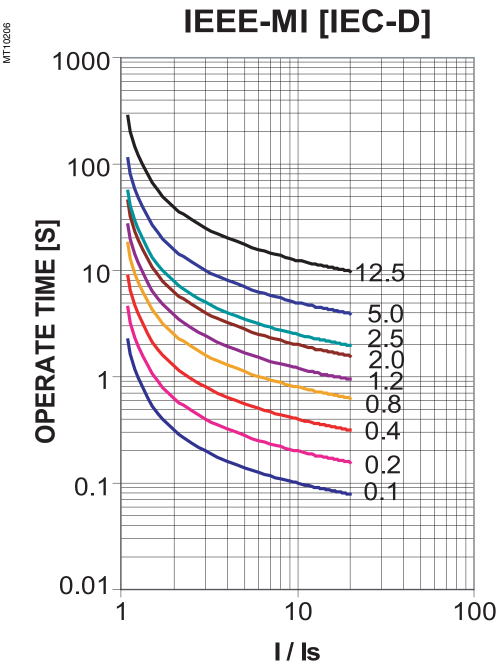
**Extremely Inverse Time (EIT) Curve**



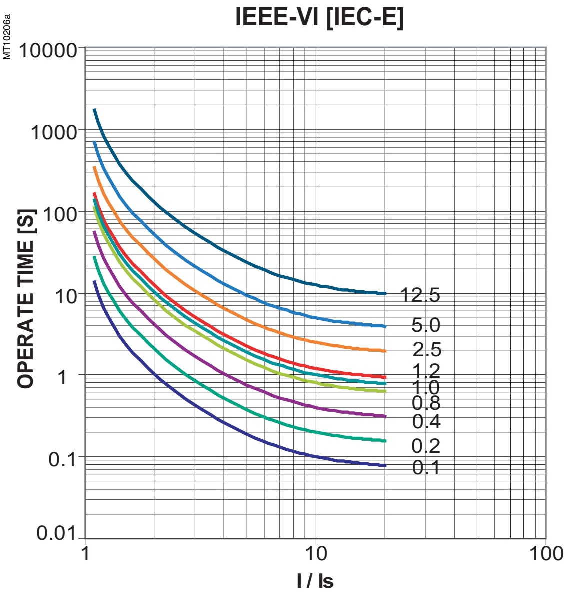
**Ultra Inverse Time (UIT) Curve**



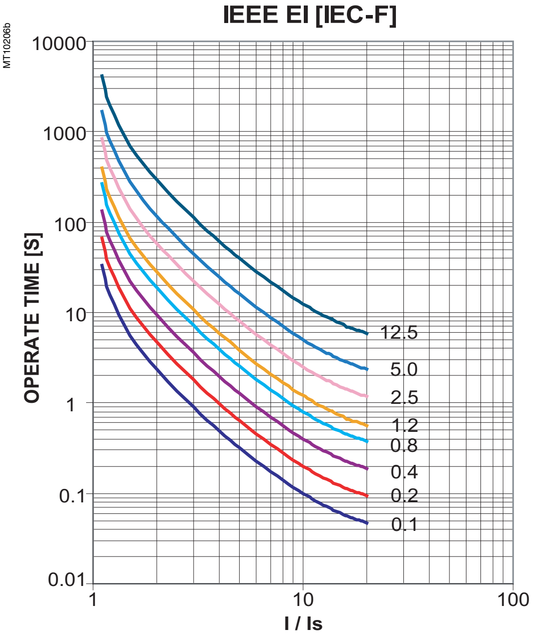
**IEEE Curves**



**IEEE Curves**

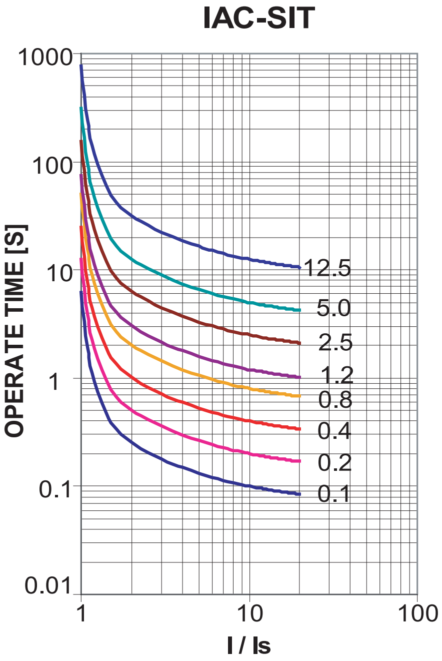


**IEEE Curves**



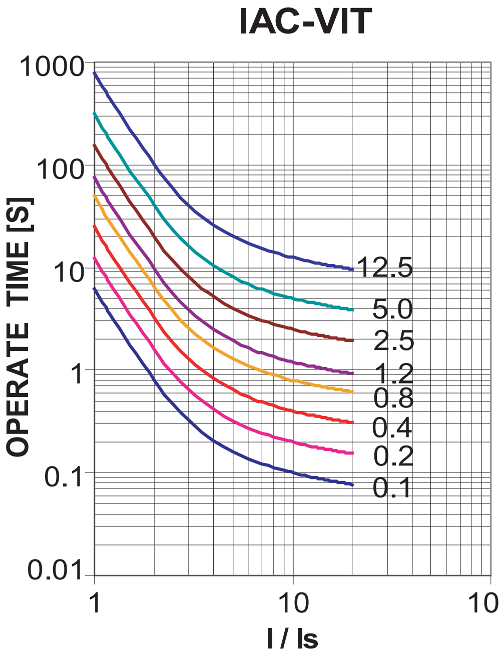
**IAC Curves**

DE50869



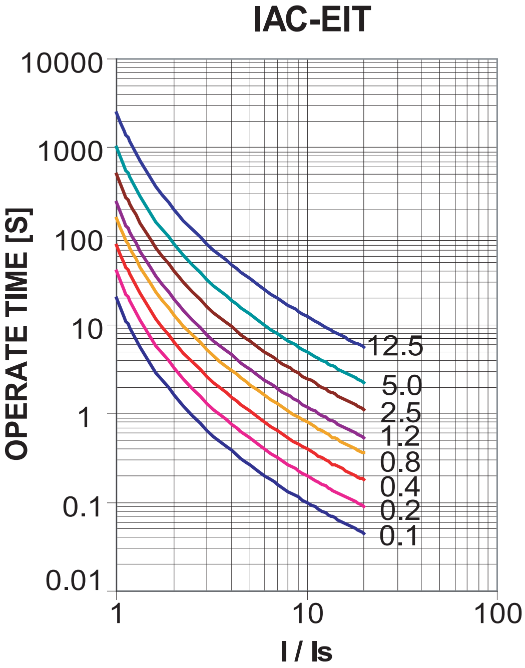
**IAC Curves**

DE50870



**IAC Curves**

MT10206



MT10207

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# Description

Sepam™ performs all the control and monitoring functions required for electrical network operation. The main control and monitoring functions are predefined and fit the most frequent cases of use. They are ready to use and are implemented by simple parameter setting after the necessary logic inputs / outputs are assigned.

The predefined control and monitoring functions can be adapted for particular needs using the SFT2841 software, which offers the following customization options:

- logic equation editor, to adapt and complete the predefined control and monitoring functions
- creation of personalized messages for local annunciation
- creation of personalized mimic diagrams corresponding to the controlled devices
- customization of the control matrix by changing the assignment of output relays, LEDs and annunciation messages

With the Logipam option, Sepam™ provides the most varied control and monitoring functions, programmed using the SFT2885 programming software that implements the Logipam ladder language.

## Operating Principle

The processing of each control and monitoring function may be broken down into three phases:

**1** acquisition of input data:
- results of protection function processing
- external logic data, connected to the logic inputs of an optional MES120 input / output module
- local control commands transmitted by the mimic-based UMI
- remote control commands (TC) received via the communication link

**2** actual processing of the control and monitoring function

**3** utilization of the processing results:
- activation of output relays to control a device
- information sent to the facility manager:
  - ☐ by message and/or LED on the Sepam™ display and SFT2841 software
  - ☐ by remote indication (TS) via the communication link
  - ☐ by real-time indications on device status on the animated mimic diagram.

## Logic Inputs and Outputs

The number of Sepam™ inputs / outputs must be adapted to fit the control and monitoring functions used.

The five outputs included in the Sepam™ Series 80 base unit may be extended by adding one, two, or three MES120 modules with 14 logic inputs and 6 output relays each.

After the number of MES120 modules needed for an application is set, the logic inputs are assigned to functions. The functions are chosen from a list that covers the whole range of possible uses. The functions are adapted to meet needs within the limits of the logic inputs available. The inputs may also be inverted for undervoltage type operation.

A default input / output assignment is proposed for the most frequent uses.

PE50249

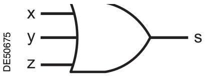
*Maximum Sepam™ series 80 configuration with 3 MES120 modules: 42 inputs and 23 outputs*

# Definition of Symbols

*This page gives the meaning of the symbols used in the block diagrams illustrating the different control and monitoring functions in this chapter.*

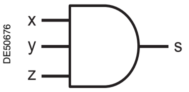
## Logic Functions

**"OR"**



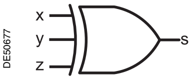
Equation: s = x **or** y **or** z.

**"AND"**



Equation: s = x **and** y **and** z.

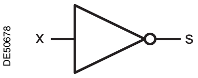
**exclusive OR "XOR"**



s = 1 if one and only one input is set to 1 (s = 1 **if** x **or** y **or** z = 1).

**Complement**

These functions may use the complement of one or more input values.

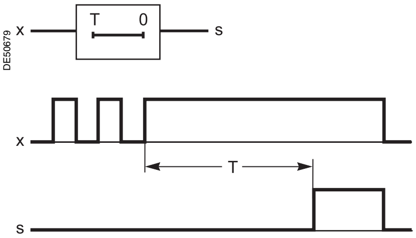


Equation: $s = \overline{x}$ (s = 1 if x = 0).

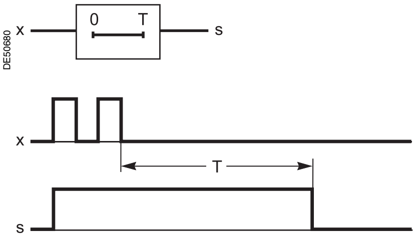
## Delay Timers

There are two types of delay timers:

- "**on**" delay timer: used to delay the appearance of a signal by a time T



- "**off**" delay timer: used to delay the disappearance of a signal by a time T.



## Pulse Mode Operation

The "on" pulse: used to create a short-duration pulse (200 ms) each time a signal appears

DE50681

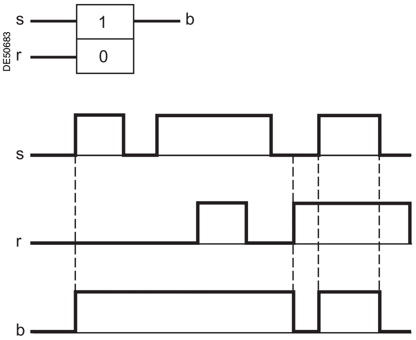
- "off" pulse: used to create a short-duration pulse (200 ms) each time a signal disappears.

DE50682

***Note :** the disappearance of a signal may be caused by an auxiliary power failure.*

## Bistable Functions

Bistable functions may be used to store values.



Equation: $B = S + \overline{R}$ x B.

# Logic Input/Output Assignment

Inputs and outputs may be assigned to predefined control and monitoring functions using the SFT2841 software, according to the uses listed in the table below. The control logic of each input may be inverted for undervoltage type operation.

All logic inputs, whether assigned to predefined functions or not, can be used for the customization functions according to specific application needs:

- in the control matrix (SFT2841 software), to connect an input to a logic output, a LED on the front of Sepam™ or a message for local indication on the display
- in the logic equation editor (SFT2841 software), as logic equation variables
- in Logipam (SFT2885 software) as input variables for the program in ladder language

## Logic Output Assignment Table

| Functions | S80 | S81 | S82 | S84 | T81 | T82<br>T87 | M87 | M81<br>M88 | G87 | G82<br>G88 | B80 | B83 | C86 | Assignment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tripping / contactor control | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | O1 |
| Block closing | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | O2 by default |
| Closing | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | O3 by default |
| Watchdog | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | O5 |
| Zone selective Interlocking, blocking send 1 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | O102 by default |
| Zone selective Interlocking, blocking send 2 |  |  | ■ | ■ |  | ■ |  |  | ■ | ■ |  |  |  | O103 by default |
| Genset shutdown |  |  |  |  |  |  |  |  | ■ | ■ |  |  |  | Free |
| De-excitation |  |  |  |  |  |  |  |  | ■ | ■ |  |  |  | Free |
| Load shedding |  |  |  |  |  |  | ■ | ■ |  |  |  |  |  | Free |
| AT, closing of NO circuit breaker | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| AT, closing of tie breaker | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| AT, opening of tie breaker | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Tripping of capacitor step (1 to 4) |  |  |  |  |  |  |  |  |  |  |  |  | ■ | Free |
| Tripping of capacitor step (1 to 4) |  |  |  |  |  |  |  |  |  |  |  |  | ■ | Free |

***Note:*** *The logic outputs assigned by default may be freely reassigned.*

## Assignment Table for Logic Inputs Common to all Applications

| Functions | S80 | S81 | S82 | S84 | T81 | T82<br>T87 | M87 | M81<br>M88 | G87 | G82<br>G88 | B80 | B83 | C86 | Assignment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Closed circuit breaker | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | I101 |
| Open circuit breaker | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | I102 |
| Synchronization of Sepam™ internal clock via external pulse | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | I103 |
| Switching of groups of settings A/B | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| External reset | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Grounding switch closed | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Grounding switch open | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| External trip 1 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| External trip 2 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| External trip 3 | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| End of charging position | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Block remote control (Local) | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| SF6 pressure default | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Block closing | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Open command | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Close command | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Phase VT fuse blown | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Vr VT fuse blown | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| External positive active energy meter | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| External negative active energy meter | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| External positive reactive energy meter | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| External negative reactive energy meter | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Racked out circuit breaker | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Switch A closed | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Switch A open | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Switch B closed | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Switch B open | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |
| Closing-coil monitoring | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Free |

# Logic Input/Output Assignment

### Assignment Table of Logic Inputs by Application

| Functions | S80 | S81 | S82 | S84 | T81 | T82 T87 | M87 | M81 M88 | G87 | G82 G88 | B80 | B83 | C86 | Assignment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Block recloser | ■ | ■ | ■ | ■ |  |  |  |  |  |  |  |  |  | Free |
| Block thermal overload |  | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | Free |
| Switching of thermal settings |  |  |  |  | ■ | ■ | ■ | ■ | ■ | ■ |  |  |  | Free |
| Blocking reception 1 | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Blocking reception 2 |  |  | ■ | ■ |  | ■ |  |  | ■ | ■ |  |  |  | Free |
| Buchholz trip |  |  |  |  | ■ | ■ |  | ■ |  | ■ |  |  |  | Free |
| Thermostat trip |  |  |  |  | ■ | ■ |  | ■ |  | ■ |  |  |  | Free |
| Pressure trip |  |  |  |  | ■ | ■ |  | ■ |  | ■ |  |  |  | Free |
| Thermistor trip |  |  |  |  | ■ | ■ | ■ | ■ | ■ | ■ |  |  |  | Free |
| Buchholz alarm |  |  |  |  | ■ | ■ |  | ■ |  | ■ |  |  |  | Free |
| Thermostat alarm |  |  |  |  | ■ | ■ |  | ■ |  | ■ |  |  |  | Free |
| Pressure alarm |  |  |  |  | ■ | ■ |  | ■ |  | ■ |  |  |  | Free |
| Thermistor alarm |  |  |  |  | ■ | ■ | ■ | ■ | ■ | ■ |  |  |  | Free |
| Rotor speed measurement |  |  |  |  |  |  | ■ | ■ | ■ | ■ |  |  |  | Ia04 |
| Rotor rotation detection |  |  |  |  |  |  | ■ | ■ |  |  |  |  |  | Free |
| Motor re-acceleration |  |  |  |  |  |  | ■ | ■ |  |  |  |  |  | Free |
| Load shedding request |  |  |  |  |  |  | ■ | ■ |  |  |  |  |  | Free |
| Block undercurrent |  |  |  |  |  |  | ■ | ■ |  |  |  |  |  | Free |
| Priority genset shutdown |  |  |  |  |  |  |  |  | ■ | ■ |  |  |  | Free |
| De-excitation |  |  |  |  |  |  |  |  | ■ | ■ |  |  |  | Free |
| Close enable (ANSI 25) | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Block opposite-side remote control (local) | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Block remote-control tie breaker (local) | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Tie Breaker open | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Tie Breaker closed | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Opposite side open | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Opposite side closed | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Selector set to Manual (ANSI 43) | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Selector set to Auto (ANSI 43) | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Selector set to Circuit breaker (ANSI 10) | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Selector set to Tie Breaker (ANSI 10) | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Opposite-side circuit breaker disconnected | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Tie Breaker circuit disconnected | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Tie Breaker close command | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Opposite-side voltage OK | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Block closing of tie breaker | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| Automatic closing command | ■ | ■ | ■ | ■ | ■ | ■ |  |  | ■ | ■ | ■ | ■ |  | Free |
| External closing command 1 |  |  |  |  |  |  |  |  |  |  | ■ | ■ |  | Free |
| External closing command 2 |  |  |  |  |  |  |  |  |  |  | ■ | ■ |  | Free |
| Additional phase voltage transformer fuse blown |  |  |  |  |  |  |  |  |  |  | ■ | ■ |  | Free |
| Additional Vr voltage transformer fuse blown |  |  |  |  |  |  |  |  |  |  |  | ■ |  | Free |

## Assignment Table of Logic Inputs by Application

| Functions | S80 | S81 | S82 | S84 | T81 | T82<br>T87 | M87 | M81<br>M88 | G87 | G82<br>G88 | B80 | B83 | C86 | Assignment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Capacitor step 1 open | | | | | | | | | | | | | ■ | Free |
| Capacitor step 1 closed | | | | | | | | | | | | | ■ | Free |
| Capacitor step 2 open | | | | | | | | | | | | | ■ | Free |
| Capacitor step 2 closed | | | | | | | | | | | | | ■ | Free |
| Capacitor step 3 open | | | | | | | | | | | | | ■ | Free |
| Capacitor step 3 closed | | | | | | | | | | | | | ■ | Free |
| Capacitor step 4 open | | | | | | | | | | | | | ■ | Free |
| Capacitor step 4 closed | | | | | | | | | | | | | ■ | Free |
| Step 1 opening command | | | | | | | | | | | | | ■ | Free |
| Step 2 opening command | | | | | | | | | | | | | ■ | Free |
| Step 3 opening command | | | | | | | | | | | | | ■ | Free |
| Step 4 opening command | | | | | | | | | | | | | ■ | Free |
| Step 1 closing command | | | | | | | | | | | | | ■ | Free |
| Step 2 closing command | | | | | | | | | | | | | ■ | Free |
| Step 3 closing command | | | | | | | | | | | | | ■ | Free |
| Step 4 closing command | | | | | | | | | | | | | ■ | Free |
| Step 1 external trip | | | | | | | | | | | | | ■ | Free |
| Step 2 external trip | | | | | | | | | | | | | ■ | Free |
| Step 3 external trip | | | | | | | | | | | | | ■ | Free |
| Step 4 external trip | | | | | | | | | | | | | ■ | Free |
| Capacitor step 1 VAR control | | | | | | | | | | | | | ■ | Free |
| Capacitor step 2 VAR control | | | | | | | | | | | | | ■ | Free |
| Capacitor step 3 VAR control | | | | | | | | | | | | | ■ | Free |
| Capacitor step 4 VAR control | | | | | | | | | | | | | ■ | Free |
| External capacitor step control block | | | | | | | | | | | | | ■ | Free |
| Manual capacitor step control | | | | | | | | | | | | | ■ | Free |
| Automatic capacitor step control | | | | | | | | | | | | | ■ | Free |

# Logic Input/Output Assignment

The table below lists the logic input assignment obtained with the SFT2841 configuration software by clicking on the "standard assignment" button.

| Functions | Standard Assignment | Application |
|---|---|---|
| Closed circuit breaker | I101 | All |
| Open circuit breaker | I102 | All |
| Blocking reception 1 | I103 | All except M8x |
| Blocking reception 2 | I104 | All except S80, S81, T81, M8x, B8x, C86 |
| Close enable (ANSI 25) | I104 | S80, S81, T81, B8x |
| SF6 pressure default | I105 | All |
| Open command | I106 | All |
| Close command | I107 | All |
| Block recloser | I108 | S80, S81 |
| Buchholz trip | I108 | T8x, M88, G88 |
| Thermostat trip | I109 | T8x, M88, G88 |
| Pressure trip | I110 | T8x, M88, G88 |
| Thermistor trip | I111 | T8x, M88, G88 |
| Buchholz alarm | I112 | T8x, M88, G88 |
| Thermostat alarm | I113 | T8x, M88, G88 |
| Pressure alarm | I114 | T8x, M88, G88 |
| Selector set to Circuit Breaker (ANSI 10) | I201 | S8x, T8x, G8x, B8x |
| Selector set to Tie Breaker (ANSI 10) | I202 | S8x, T8x, G8x, B8x |
| Selector set to Auto (ANSI 43) | I203 | S8x, T8x, G8x, B8x |
| Selector set to Manual (ANSI 43) | I204 | S8x, T8x, G8x, B8x |
| Opposite side closed | I205 | S8x, T8x, G8x, B8x |
| Opposite side open | I206 | S8x, T8x, G8x, B8x |
| Opposite-side voltage OK | I207 | S8x, T8x, G8x, B8x |
| Block opposite side remote control (local) | I208 | S8x, T8x, G8x, B8x |
| Automatic closing command | I209 | S8x, T8x, G8x, B8x |
| Tie Breaker open | I210 | S8x, T8x, G8x, B8x |
| Tie Breaker closed | I211 | S8x, T8x, G8x, B8x |
| Block closing of tie breaker | I212 | S8x, T8x, G8x, B8x |
| Tie Breaker close command | I213 | S8x, T8x, G8x, B8x |
| Block remote-control tie breaker (local) | I214 | S8x, T8x, G8x, B8x |

# Switchgear Control
ANSI Code 94/69

*Predefined circuit breaker or contactor control function.*

## Operation

The Switchgear control function can control the following types of breaking device:

- circuit breakers with NO or NC contacts
- latching contactors with NO contacts
- contactors with latched commands.

This function comprises two parts:

- processing of internal switchgear control commands:
  - open $\boxed{1}$, $\boxed{2}$, $\boxed{3}$
  - close with or without sync-check $\boxed{6}$, $\boxed{7}$, $\boxed{8}$
  - block closing $\boxed{4}$, $\boxed{5}$
- execution of internal commands by control logic outputs according to the type of device to be controlled.

### Processing Internal Switchgear Control Commands

The Switchgear control function processes all breaking device closing and tripping conditions, based on:

- protection functions (configured to trip the breaking device)
- breaking device status data
- remote control via the communication link
- local control commands by logic input or mimic-based UMI
- internal control commands created by logic equation or Logipam
- specific predefined control functions for each application:
  - recloser
  - genset shutdown, de-excitation
  - load shedding
  - sync-check
  - automatic transfer
  - capacitor step control.

The function also blocks breaking device closing, according to the operating conditions.

### Anti-Pumping Function

To prevent simultaneous breaking device open and close commands and to give priority to open commands, breaker device close commands are of the pulse type.

### Switchgear Control with Lockout Function (ANSI 86)

The ANSI 86 function traditionally performed by lockout relays may be ensured by Sepam™ using the Switchgear control function, with latching of all the tripping conditions (protection function outputs and logic inputs).
Sepam™ performs the following functions:

- grouping the tripping conditions and breaking device control
- latching the tripping command, with closing block, until the cause of tripping disappears and is acknowledged by the user (see Latching / acknowledgement function)
- indication of the cause of tripping:
  - locally by LEDs (Trip and others) and by messages on the display
  - remotely by remote indications (see Indications function).

### Closing with Sync-Check $\boxed{9}$

The Sync-check function checks the voltages upstream and downstream of a circuit breaker to ensure safe closing. It is put into service by parameter setting.

For sync-check to operate, one of the “Close enable” logic outputs of an MCS025 remote module must be connected to a Sepam™ logic input assigned to the Close enable function.

If it is necessary to close the circuit breaker without taking into account the synchronization conditions, this may be done by a logic equation or by Logipam via the V_CLOSE_NOCTRL input.

### Controlling Logic Outputs

Logic commands from the Switchgear control function are used to control the Sepam™ logic outputs that control breaking device opening and closing.

Logic output control is set up to match the device to be controlled, i.e. a circuit breaker or contactor.

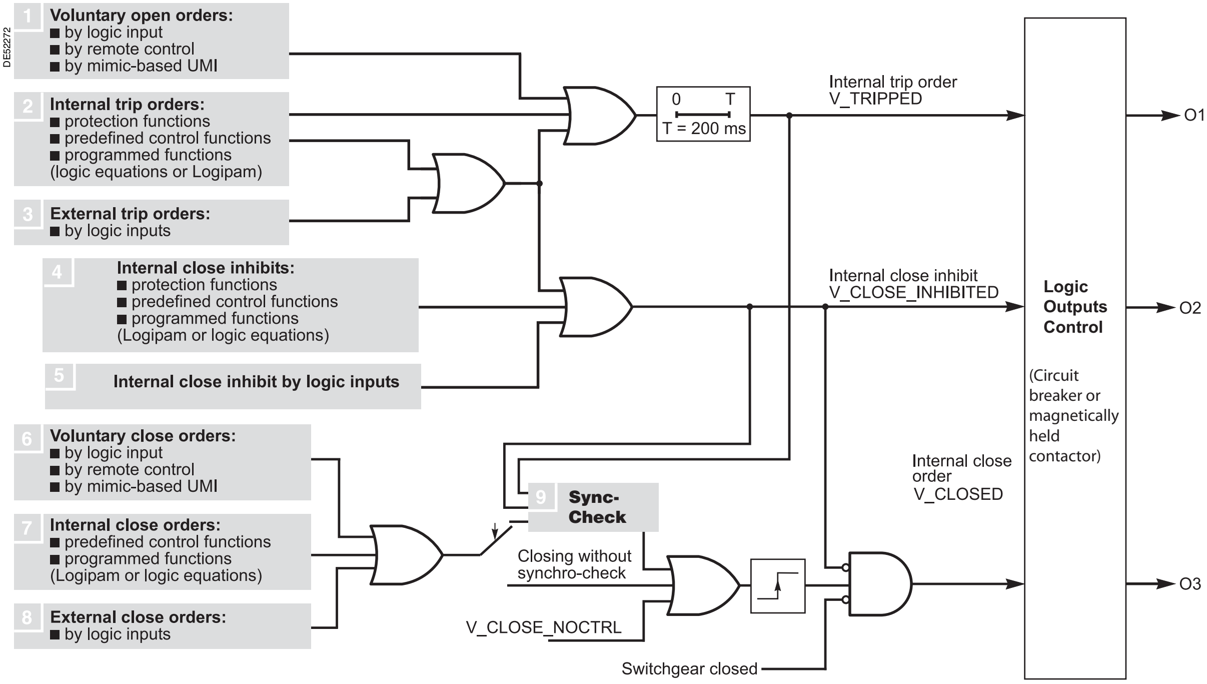
### Controlling Capacitor Banks

The Sepam™ C86 Switchgear control function can control the breaking device and 1 to 4 capacitor step switches.

This particular function is described separately.

## Processing Internal Switchgear Control Commands

### Block Diagram


DE52272
1 Voluntary open orders:
■ by logic input
■ by remote control
■ by mimic-based UMI
2 Internal trip orders:
■ protection functions
■ predefined control functions
■ programmed functions
(logic equations or Logipam)
3 External trip orders:
■ by logic inputs
4 Internal close inhibits:
■ protection functions
■ predefined control functions
■ programmed functions
(Logipam or logic equations)
5 Internal close inhibit by logic inputs
6 Voluntary close orders:
■ by logic input
■ by remote control
■ by mimic-based UMI
7 Internal close orders:
■ predefined control functions
■ programmed functions
(Logipam or logic equations)
8 External close orders:
■ by logic inputs
0 T
T = 200 ms
Internal trip order
V_TRIPPED
Internal close inhibit
V_CLOSE_INHIBITED
9 Sync-Check
Closing without synchro-check
V_CLOSE_NOCTRL
Switchgear closed
Internal close order
V_CLOSED
Logic Outputs Control
(Circuit breaker or magnetically held contactor)
O1
O2
O3

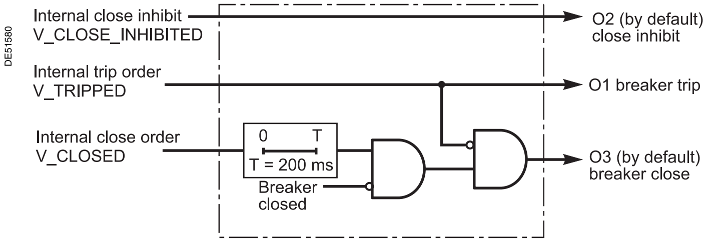
## Control of Logic Outputs

### Controlling a Circuit Breaker or Contactor with Mechanical Latching

The block diagram below represents the following parameter setting:

- type of switchgear = Circuit Breaker
- output O1 = trip
- output O2 = close block
- output O3 = close.

(See Logic diagram above)

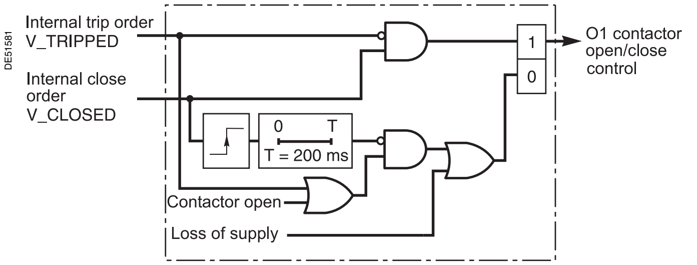

DE51580
Internal close inhibit
V_CLOSE_INHIBITED
Internal trip order
V_TRIPPED
Internal close order
V_CLOSED
0 T
T = 200 ms
Breaker closed
O2 (by default) close inhibit
O1 breaker trip
O3 (by default) breaker close

### Controlling a Contactor Without Mechanical Latching

The block diagram below represents the following parameter setting:

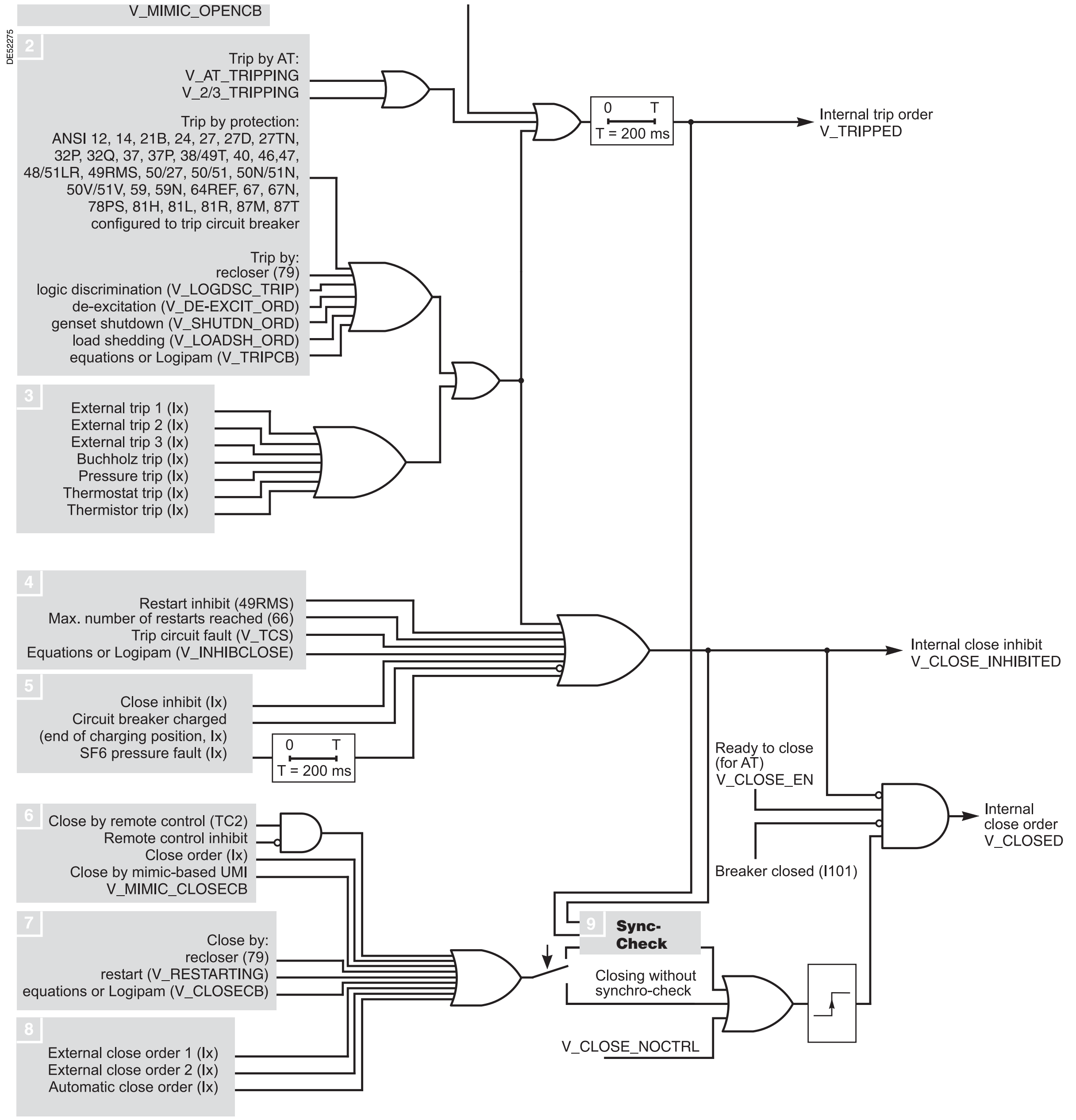
- type of switchgear = Contactor
- output O1 = open / close.

(See Logic diagram above)


DE51581
Internal trip order
V_TRIPPED
Internal close order
V_CLOSED
0 T
T = 200 ms
Contactor open
Loss of supply
1
0
O1 contactor open/close control

## Processing Internal Switchgear Control Commands

### Block Diagram


DE52275
V_MIMIC_OPENCB
2
Trip by AT:
V_AT_TRIPPING
V_2/3_TRIPPING
Trip by protection:
ANSI 12, 14, 21B, 24, 27, 27D, 27TN, 32P, 32Q, 37, 37P, 38/49T, 40, 46,47, 48/51LR, 49RMS, 50/27, 50/51, 50N/51N, 50V/51V, 59, 59N, 64REF, 67, 67N, 78PS, 81H, 81L, 81R, 87M, 87T configured to trip circuit breaker
Trip by:
recloser (79)
logic discrimination (V_LOGDSC_TRIP)
de-excitation (V_DE-EXCIT_ORD)
genset shutdown (V_SHUTDN_ORD)
load shedding (V_LOADSH_ORD)
equations or Logipam (V_TRIPCB)
0 T
T = 200 ms
Internal trip order
V_TRIPPED
3
External trip 1 (Ix)
External trip 2 (Ix)
External trip 3 (Ix)
Buchholz trip (Ix)
Pressure trip (Ix)
Thermostat trip (Ix)
Thermistor trip (Ix)
4
Restart inhibit (49RMS)
Max. number of restarts reached (66)
Trip circuit fault (V_TCS)
Equations or Logipam (V_INHIBCLOSE)
Internal close inhibit
V_CLOSE_INHIBITED
5
Close inhibit (Ix)
Circuit breaker charged (end of charging position, Ix)
SF6 pressure fault (Ix)
0 T
T = 200 ms
Ready to close (for AT)
V_CLOSE_EN
Internal close order
V_CLOSED
Breaker closed (I101)
6
Close by remote control (TC2)
Remote control inhibit
Close order (Ix)
Close by mimic-based UMI
V_MIMIC_CLOSECB
7
Close by:
recloser (79)
restart (V_RESTARTING)
equations or Logipam (V_CLOSECB)
9
Sync-Check
Closing without synchro-check
V_CLOSE_NOCTRL
8
External close order 1 (Ix)
External close order 2 (Ix)
Automatic close order (Ix)

## Close Enable by the Sync-Check Function

**Operation**
The close request, made locally or remotely, is maintained by Sepam™ during the close request delay and triggers the appearance of a "SYNC.IN PROCESS" message. It is deactivated when a tripping command or circuit breaker blocking command is received and triggers the "STOP SYNC." message.

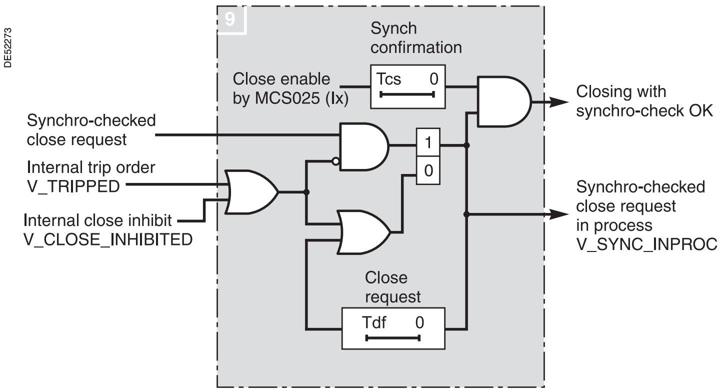
The closing command is given if the close enable is received before the close request delay runs out. When this is the case, the message "SYNC. OK" is displayed.

If the close enable is not received, the message "SYNC. FAILURE" is displayed. When possible and if the MCS025 remote module is connected by the CCA785 cord to the Sepam™ to which the close request has been made, an additional message indicates the type of synchronization failure:

- "SYNC. FAILED dU" for too high a voltage difference
- "SYNC. FAILED DF" for too high a frequency difference
- "SYNC. FAILED dPhi" for too high a phase difference.

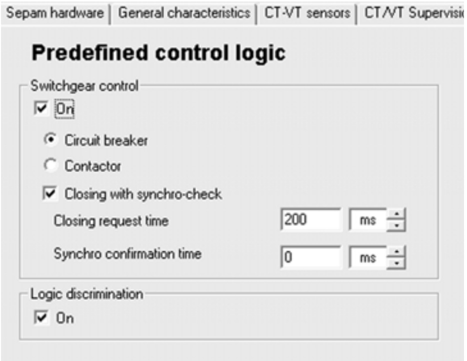
An additional delay is used to confirm the close enable to guarantee that the closing conditions last long enough.

**Block Diagram**


DE52273
9
Synch confirmation
Close enable by MCS025 (Ix)
Tcs 0
Closing with synchro-check OK
Synchro-checked close request
1
0
Internal trip order V_TRIPPED
Internal close inhibit V_CLOSE_INHIBITED
Synchro-checked close request in process V_SYNC_INPROC
Close request
Tdf 0

## Parameter Setting

The Switchgear control function is set up and adapted to match the type of breaking device to be controlled using the SFT2841 software.



**Predefined control logic**

Switchgear control
☑ On
● Circuit breaker
○ Contactor
☑ Closing with synchro-check
Closing request time 200 ms
Synchro confirmation time 0 ms

Logic discrimination
☑ On

*SFT2841: parameter setting of Switchgear control*

**"Control Logic" Tab**

- activation of the Switchgear control function
- choice of the type of breaking device to be controlled: circuit breaker (by default) or contactor
- activation of the Sync-check function, if necessary.

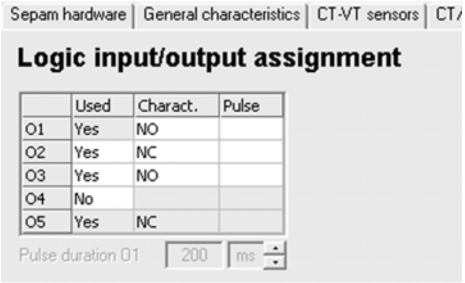
**"Logic I/Os" Tab**

- assignment of the logic inputs required
- definition of logic output behavior.

By default, the following outputs are used:

| Logic Output | Associated Internal Command | Circuit Breaker Contacts |
|---|---|---|
| O1 | Trip<br>(V_TRIPPED) | Normally Open (NO) |
| O2 | Close block<br>(V_CLOSE_BLOCKED) | Normally Closed (NC) |
| O3 | Close<br>(V_CLOSED) | Normally Open (NO) |

- the Trip command is always associated with output O1.
  If output O1 is set up for pulse type operation, the pulse command duration may be set up
- the optional Close block and Close commands may be assigned to any logic output.



**Logic input/output assignment**

| | Used | Charact. | Pulse |
|---|---|---|---|
| O1 | Yes | NO | |
| O2 | Yes | NC | |
| O3 | Yes | NO | |
| O4 | No | | |
| O5 | Yes | NC | |

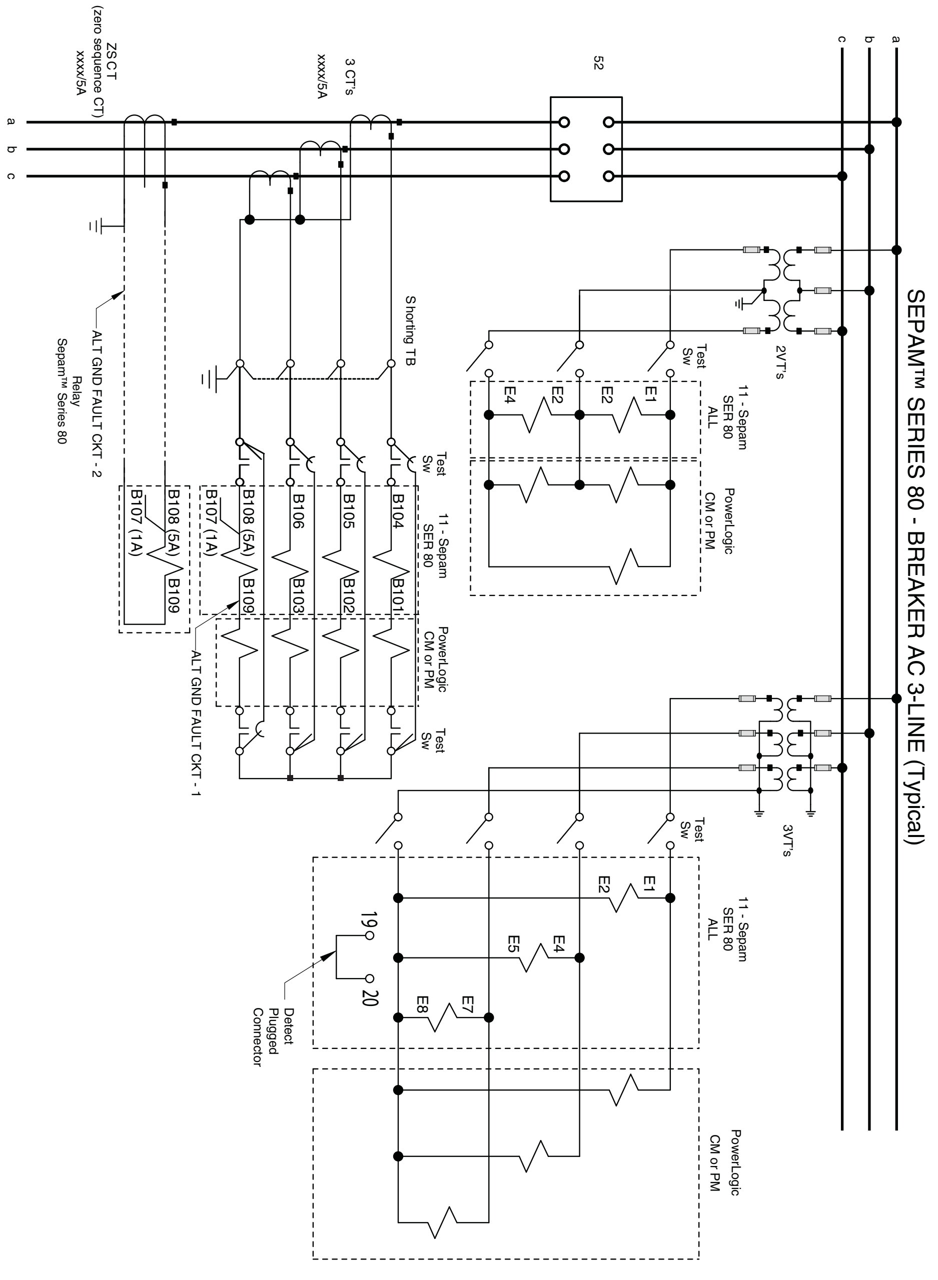
Pulse duration O1 200 ms

*SFT2841: default parameter setting of the logic outputs assigned to Switchgear control*

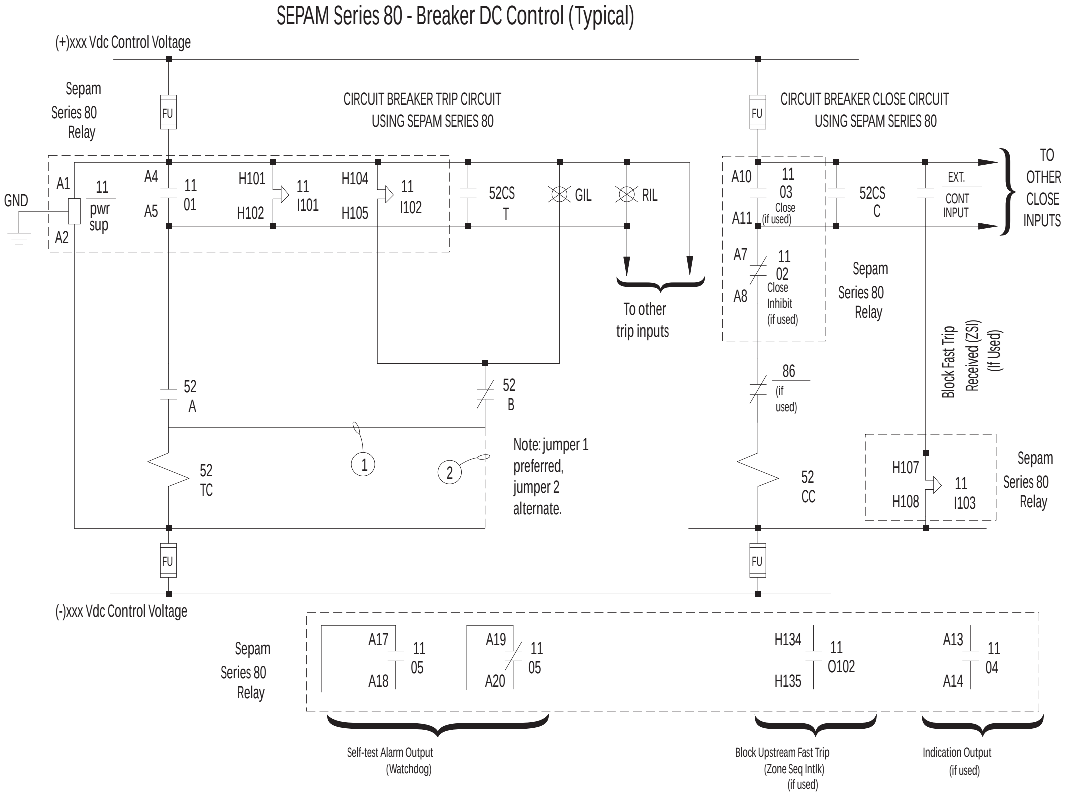
**"Matrix" Screen, "Logic" Button**

Modification of the default internal command assignment to outputs O2 and O3, if necessary.

# Switchgear Control
## Typical Breaker & Contactor Diagrams
### Breaker AC 3-Line (Typical)

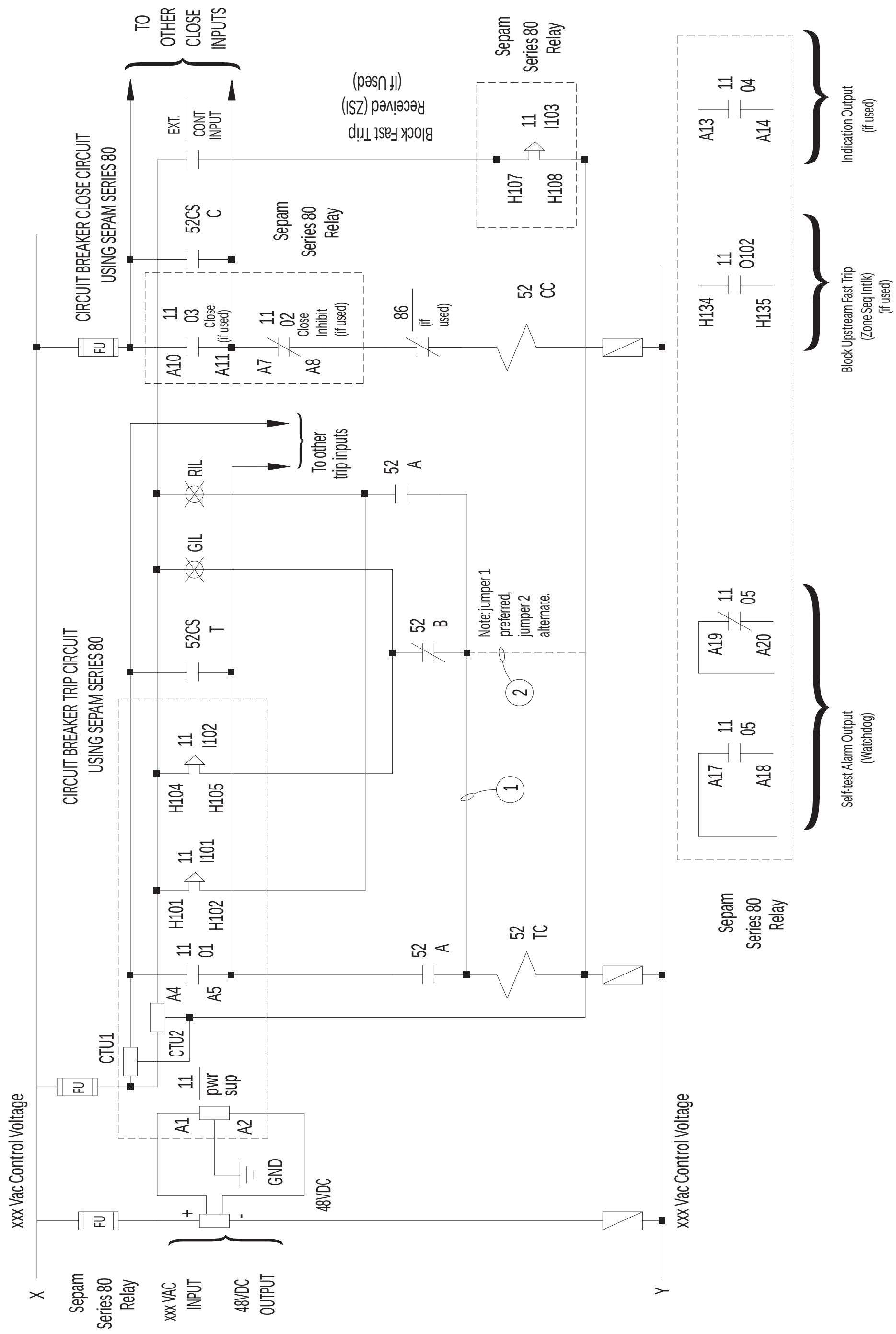

SEPAM™ SERIES 80 - BREAKER AC 3-LINE (Typical)
a
b
c
52
3 CT's
xxxx/5A
ZS CT
(zero sequence CT)
xxxx/5A
a
b
c
2VT's
3VT's
Test Sw
Shorting TB
11 - Sepam SER 80 ALL
PowerLogic CM or PM
E1
E2
E2
E4
11 - Sepam SER 80
B104
B105
B106
B108 (5A)
B107 (1A)
B101
B102
B103
B109
B108 (5A)
B107 (1A)
B109
ALT GND FAULT CKT - 2
Relay
Sepam™ Series 80
ALT GND FAULT CKT - 1
E1
E2
E4
E5
E7
E8
19
20
Detect Plugged Connector

# **Switchgear Control**
## Typical Breaker & Contactor Diagrams
### Breaker DC Control (Typical)

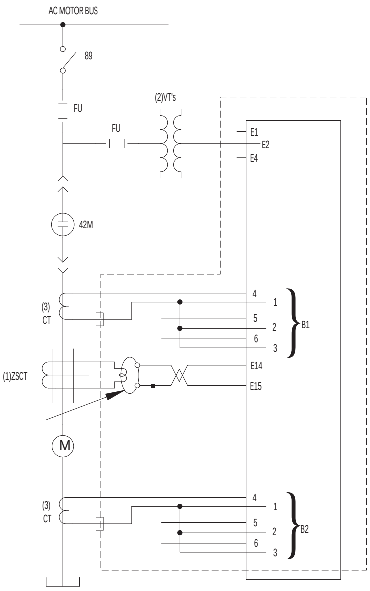

SEPAM Series 80 - Breaker DC Control (Typical)
(+)xxx Vdc Control Voltage
Sepam Series 80 Relay
FU
CIRCUIT BREAKER TRIP CIRCUIT USING SEPAM SERIES 80
CIRCUIT BREAKER CLOSE CIRCUIT USING SEPAM SERIES 80
GND
A1
A2
11 pwr sup
A4
A5
11 01
H101
H102
11 I101
H104
H105
11 I102
52CS T
GIL
RIL
To other trip inputs
A10
A11
11 03 Close (if used)
A7
A8
11 02 Close Inhibit (if used)
52CS C
EXT. CONT INPUT
TO OTHER CLOSE INPUTS
Block Fast Trip Received (ZSI) (If Used)
52 A
52 B
1
2
Note: jumper 1 preferred, jumper 2 alternate.
52 TC
86 (if used)
52 CC
H107
H108
11 I103
(-)xxx Vdc Control Voltage
A17
A18
11 05
A19
A20
11 05
H134
H135
11 O102
A13
A14
11 04
Self-test Alarm Output (Watchdog)
Block Upstream Fast Trip (Zone Seq Intlk) (if used)
Indication Output (if used)

# Switchgear Conrtol
## Typical Breaker & Contactor Diagrams
### Breaker AC Control (Typical)

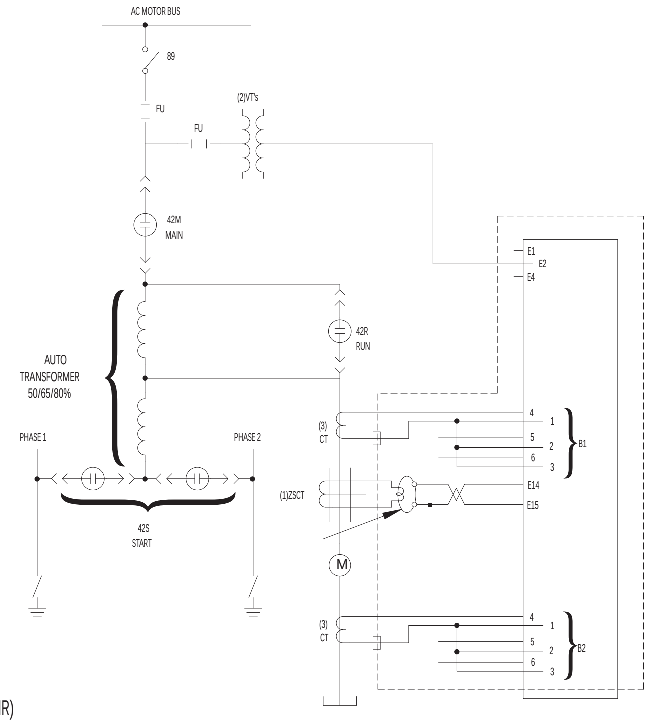
SEPAM Series 80 - Breaker AC Control (Typical)


TO OTHER CLOSE INPUTS
CIRCUIT BREAKER CLOSE CIRCUIT USING SEPAM SERIES 80
CIRCUIT BREAKER TRIP CIRCUIT USING SEPAM SERIES 80
EXT. CONT INPUT
52CS C
52CS T
Sepam Series 80 Relay
Block Fast Trip Received (ZSI) (If Used)
11 I103
H107
H108
A10
A11
11 03 Close (if used)
A7
A8
11 02 Close Inhibit (if used)
86 (if used)
52 CC
FU
To other trip inputs
RIL
GIL
52 A
52 B
Note: jumper 1 preferred, jumper 2 alternate.
2
1
H104
H105
11 I102
H101
H102
11 I101
11 01
A4
A5
52 A
52 TC
CTU1
CTU2
11 pwr sup
A1
A2
GND
48VDC
+
-
xxx Vac Control Voltage
X
Y
xxx VAC INPUT
48VDC OUTPUT
A13
A14
11 04
Indication Output (if used)
H134
H135
11 O102
Block Upstream Fast Trip (Zone Seq Intlk) (if used)
A19
A20
11 05
A17
A18
11 05
Self-test Alarm Output (Watchdog)

## Motor AC Contactor 1-Line


AC MOTOR BUS
89
FU
(2)VT's
FU
E1
E2
E4
42M
(3)
CT
4
5
6
1
2
3
B1
(1)ZSCT
E14
E15
M
(3)
CT
4
5
6
1
2
3
B2

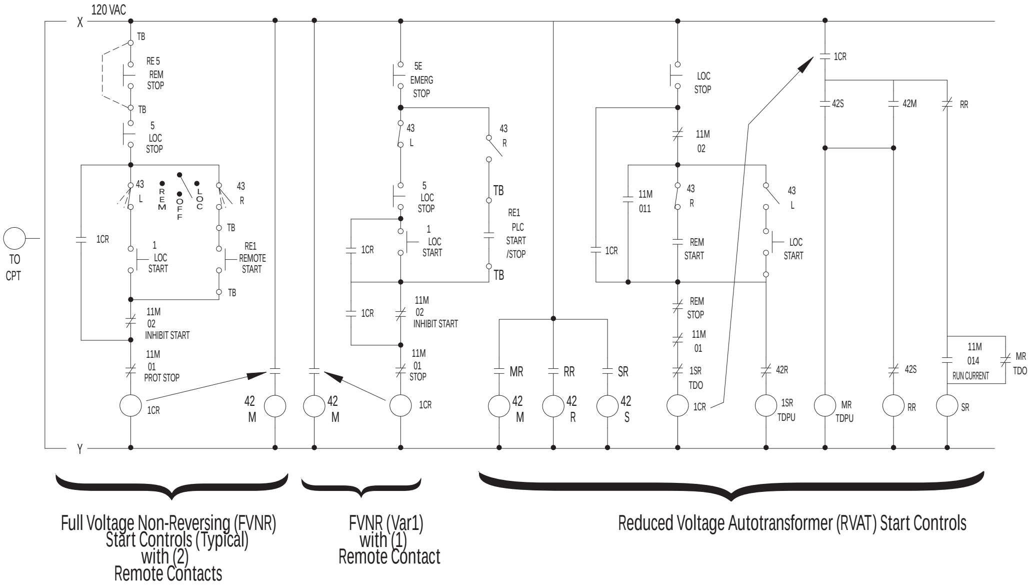
Series 80/Full Voltage Non-Reversing (FVNR)


AC MOTOR BUS
89
FU
(2)VT's
FU
42M
MAIN
E1
E2
E4
AUTO
TRANSFORMER
50/65/80%
42R
RUN
PHASE 1
PHASE 2
42S
START
(3)
CT
4
5
6
1
2
3
B1
(1)ZSCT
E14
E15
M
(3)
CT
4
5
6
1
2
3
B2

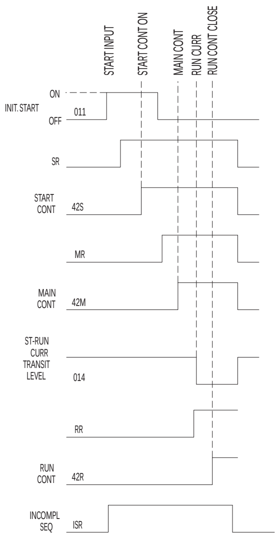
Series 80/Reduced Voltage Autotransformer (RVAT)

# Switchgear Control
## Motor AC Contactor Control
### Timing Diagram

SEPAM Series 80/Motor AC Contactor Control


120 VAC
X
Y
TO CPT
TB
RE 5 REM STOP
5 LOC STOP
43 L
REM
OFF
LOC
43 R
1CR
1 LOC START
RE1 REMOTE START
11M 02 INHIBIT START
11M 01 PROT STOP
42 M
5E EMERG STOP
43 L
43 R
5 LOC STOP
RE1 PLC START /STOP
1 LOC START
11M 02 INHIBIT START
11M 01 STOP
MR
RR
SR
42 M
42 R
42 S
LOC STOP
11M 02
11M 011
43 R
43 L
REM START
LOC START
REM STOP
11M 01
1SR TDO
42R
1SR TDPU
MR TDPU
1CR
42S
42M
RR
11M 014 RUN CURRENT
MR TDO
Full Voltage Non-Reversing (FVNR) Start Controls (Typical) with (2) Remote Contacts
FVNR (Var1) with (1) Remote Contact
Reduced Voltage Autotransformer (RVAT) Start Controls

Timing Diagram


START INPUT
START CONT ON
MAIN CONT
RUN CURR
RUN CONT CLOSE
INIT. START
ON
OFF
011
SR
START CONT
42S
MR
MAIN CONT
42M
ST-RUN CURR TRANSIT LEVEL
014
RR
RUN CONT
42R
INCOMPL SEQ
ISR

# Switchgear Control
## ANSI Code 94/69

### Characteristics

| **Settings** | |
|---|---|
| **Switchgear Control** | |
| Setting range | On / Off |
| **Type of Device** | |
| Setting range | Circuit breaker / Contactor |
| **Tripping Pulse Duration (Output O1)** | |
| Setting range | 200 ms to 300 s |
| Accuracy [(1)] | ±2% or from -10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |
| **Closing with Sync-Check** | |
| Setting range | On / Off |
| **Close Request Time Delay Tdf** | |
| Setting range | 0 to 300 s |
| Accuracy [(1)] | ±2% or from -10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |
| **Sync Confirmation Time Delay Tcs** | |
| Setting range | 0 to 300 s |
| Accuracy [(1)] | ±2% or from -10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Tripping, opening | V_TRIPCB | ■ | ■ |
| Block closing | V_BLOCKCLOSE | ■ | ■ |
| Closing | V_CLOSECB | ■ | ■ |
| Closing without sync-check | V_CLOSE_NOCTRL | ■ | ■ |

**Outputs**

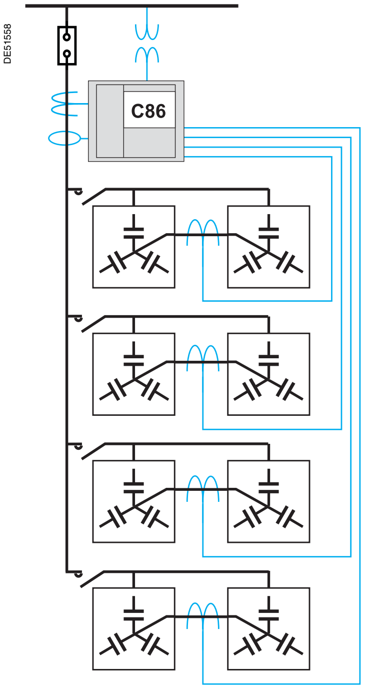
| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Switchgear control on | V_SWCTRL_ON | | ■ | |
| Tripping, opening | V_TRIPPED | ■ | ■ | ■ |
| Block closing | V_BLOCK_CLOSE | ■ | ■ | ■ |
| Closing | V_CLOSED | ■ | ■ | ■ |
| Contactor control | V_CONTACTOR | | ■ | ■ |
| Sync-check on | V_SYNC_ON | | ■ | ■ |
| Sync-check close request in process | V_SYNC_INPROC | | ■ | ■ |
| Sync-check close request stop | V_SYNC_STOP | | ■ | ■ |
| Sync-check close request successful | V_SYNC_OK | | ■ | ■ |
| Sync-check close request failure | V_NOSYNC | | ■ | ■ |
| Sync-check close request failure - Voltage difference too high | V_NOSYNC_DU | | ■ | ■ |
| Sync-check close request failure - Frequency difference too high | V_NOSYNC_DF | | ■ | ■ |
| Sync-check close request failure - Phase difference too high | V_NOSYNC_DPHI | | ■ | ■ |

***(1)** Under reference conditions (IEC 60255-6).*

# Capacitor Bank Switchgear Control

## ANSI Code 94/69

*Predefined function for the control of circuit breakers protecting capacitor banks and the switches of each capacitor bank step.*
*This function only concerns Sepam™ C86 units.*



*Example of a Sepam™ C86 application: circuit breaker protection of a 4-step capacitor bank*

### Operation

The Sepam™ C86 Switchgear control function performs:

- control of the circuit breaker protecting the capacitor bank (circuit breaker with normally open, **NO,** or normally closed, **NC**, contacts)
- control of the capacitor bank step switches (maximum of 4 steps), with processing of:
  - ☐ voluntary manual control commands
  - ☐ automatic control commands, received from reactive-energy regulators

### Control of Logic Outputs

The logic commands from the Switchgear control function are used to control the Sepam™ logic outputs which control:

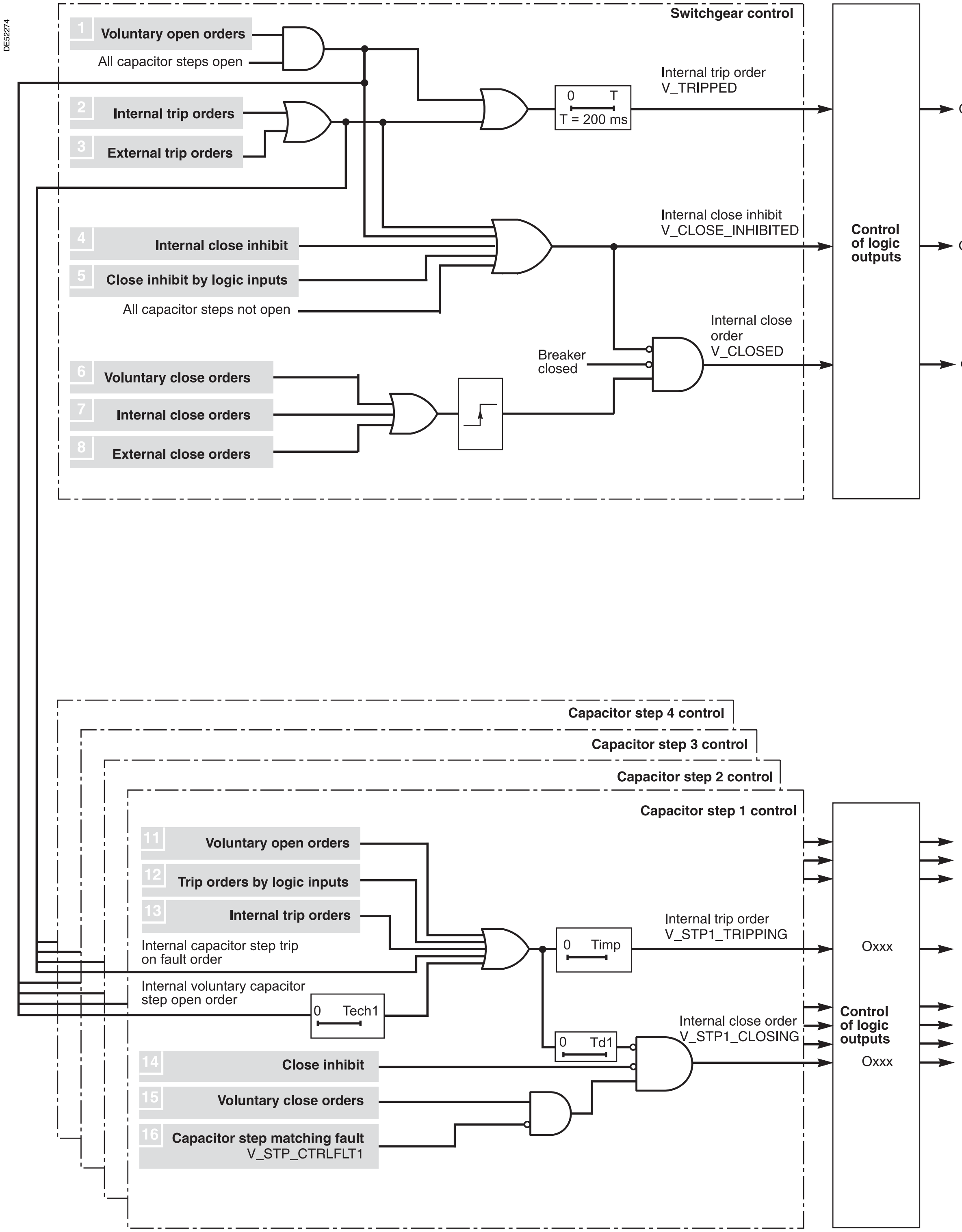
- opening and closing of the circuit breaker.
- opening and closing of each capacitor step switch.

Logic output control is set up to match the type of device to be controlled, like a circuit breaker or capacitor step switch.

# Capacitor Bank Switchgear Control
ANSI Code 94/69

## Processing Internal Switchgear Commands

### Block Diagram


DE52274
Switchgear control
1 Voluntary open orders
All capacitor steps open
2 Internal trip orders
3 External trip orders
0 T
T = 200 ms
Internal trip order
V_TRIPPED
4 Internal close inhibit
5 Close inhibit by logic inputs
All capacitor steps not open
Internal close inhibit
V_CLOSE_INHIBITED
Breaker closed
Internal close order
V_CLOSED
6 Voluntary close orders
7 Internal close orders
8 External close orders
Control of logic outputs
O1
O2
O3
Capacitor step 4 control
Capacitor step 3 control
Capacitor step 2 control
Capacitor step 1 control
11 Voluntary open orders
12 Trip orders by logic inputs
13 Internal trip orders
Internal capacitor step trip on fault order
Internal voluntary capacitor step open order
0 Tech1
0 Timp
Internal trip order
V_STP1_TRIPPING
0 Td1
Internal close order
V_STP1_CLOSING
14 Close inhibit
15 Voluntary close orders
16 Capacitor step matching fault
V_STP_CTRLFLT1
Oxxx
Control of logic outputs
Oxxx

# Capacitor Bank Switchgear Control
ANSI Code 94/69

## Controlling the Circuit Breaker

This function comprises two parts:

1. processing of internal circuit breaker control commands:
   - open circuit breaker $\boxed{1}$, $\boxed{2}$, $\boxed{3}$
   - close circuit breaker $\boxed{6}$, $\boxed{7}$, $\boxed{8}$
   - block circuit breaker closing $\boxed{4}$, $\boxed{5}$
2. executing internal commands by control logic outputs according to the type of device to be controlled.

### Processing Internal Circuit Breaker Control Commands

The Switchgear control function processes all the circuit breaker close and trip conditions, based on

- protection functions (configured to trip the circuit breaker)
- circuit breaker and capacitor step switch status data
- remote control commands via the communication link
- local control commands by logic input or mimic-based UMI
- internal control commands created by logic equation or Logipam.

The function also blocks circuit breaker closing according to the operating conditions.

### Circuit Breaker Opening

The circuit breakers open under two conditions:

1. ***Voluntary open*** – A circuit breaker open command triggers the staggered opening of capacitor step switches. This command is maintained for a time T1, the time required for the staggered opening of the capacitor step switches and the circuit breaker. The circuit breaker opens after all the capacitor step switches to avoid breaking the capacitive current.
2. ***Trip*** – The protection functions (units configured to trip the circuit breaker and external protection units) send a trip command to the circuit breaker. After the circuit breaker opens, an open command is sent to all the capacitor step switches at the same time.

### Circuit Breaker Closing

The circuit breaker only closes if all the capacitor step switches are open.

### Anti-Pumping Function

To prevent simultaneous breaking device open and close commands and to give priority to open commands, breaker device close commands are of the pulse type

### Switchgear Control with Lockout Function (ANSI 86)

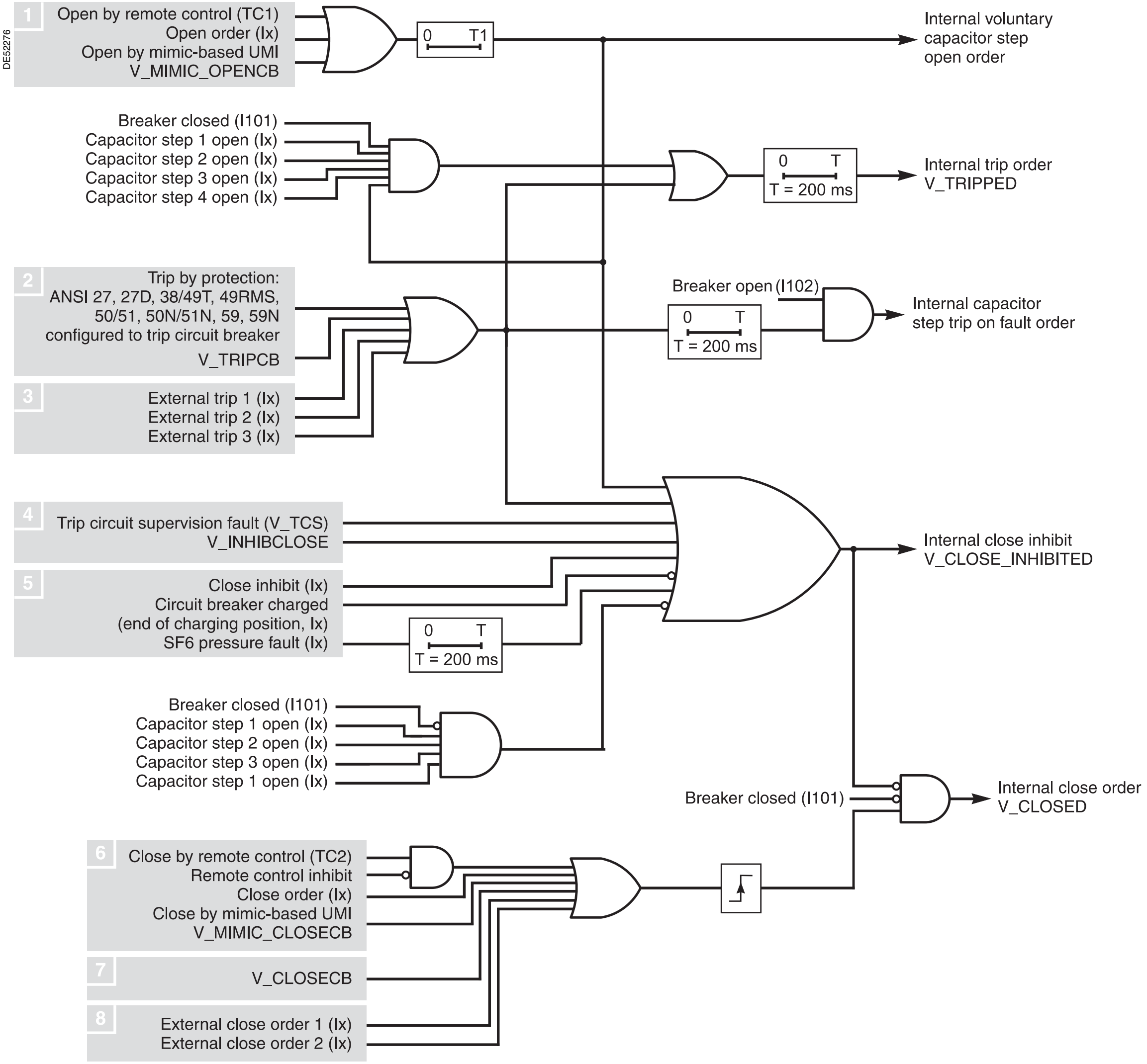
The ANSI 86 function usually performed by lockout relays can be provided by Sepam™ by using the Switchgear control function, with latching of all the tripping conditions (protection function outputs and logic inputs). Under these conditions Sepam™ performs the following:

- grouping all tripping conditions and circuit breaker control
- latching the trip command, with blocking of closing, until the cause of tripping disappears and is acknowledged by the user (see Latching / acknowledgement function)
- indicating the cause of tripping:
  - locally by LEDs (Trip and others) and by messages on the display
  - remotely by remote indications (see Indications function).

# Capacitor Bank Switchgear Control
ANSI Code 94/69

## Processing Internal Switchgear Commands

### Block Diagram


DE52276
1
Open by remote control (TC1)
Open order (Ix)
Open by mimic-based UMI
V_MIMIC_OPENCB
0 T1
Internal voluntary capacitor step open order
Breaker closed (I101)
Capacitor step 1 open (Ix)
Capacitor step 2 open (Ix)
Capacitor step 3 open (Ix)
Capacitor step 4 open (Ix)
0 T
T = 200 ms
Internal trip order
V_TRIPPED
2
Trip by protection:
ANSI 27, 27D, 38/49T, 49RMS, 50/51, 50N/51N, 59, 59N configured to trip circuit breaker
V_TRIPCB
Breaker open (I102)
0 T
T = 200 ms
Internal capacitor step trip on fault order
3
External trip 1 (Ix)
External trip 2 (Ix)
External trip 3 (Ix)
4
Trip circuit supervision fault (V_TCS)
V_INHIBCLOSE
Internal close inhibit
V_CLOSE_INHIBITED
5
Close inhibit (Ix)
Circuit breaker charged (end of charging position, Ix)
SF6 pressure fault (Ix)
0 T
T = 200 ms
Breaker closed (I101)
Capacitor step 1 open (Ix)
Capacitor step 2 open (Ix)
Capacitor step 3 open (Ix)
Capacitor step 1 open (Ix)
Breaker closed (I101)
Internal close order
V_CLOSED
6
Close by remote control (TC2)
Remote control inhibit
Close order (Ix)
Close by mimic-based UMI
V_MIMIC_CLOSECB
7
V_CLOSECB
8
External close order 1 (Ix)
External close order 2 (Ix)

# Capacitor Bank Switchgear Control
ANSI Code 94/69

## Capacitor Step Control

### Automatic Control
When the "Automatic capacitor step control" logic input is on, each step is controlled automatically by the reactive energy regulator (VAR). In this case, one input per step is used to open and close one capacitor step switch:
- input in state 1: closing of capacitor step x switch
- input in state 0: opening of capacitor step x switch.

### Manual Control
When the "Manual capacitor step control" logic input is on, each step may be opened and closed manually:
- locally by specific logic inputs (one open input and one close input per step)
- remotely by remote control.

### Blocking Voluntary Capacitor Step Control
Voluntary capacitor step switch control can be blocked by a logic input. However, this input does not block fault tripping or opening after circuit breaker opening.

### Capacitor Step Opening
Any opening of a capacitor step, whether voluntary or by tripping, activates a discharge time delay which blocks closing to ensure that the step capacitors discharge correctly.
- voluntary open: manual or automatic capacitor step switch control command
- trip, triggered by:
  - ANSI 51C unbalance protection units associated with the capacitor step and configured to trip the step $\boxed{13}$
  - "Tripping of step x" logic input (one input per capacitor step) $\boxed{12}$
  - logic equation or Logipam $\boxed{13}$.

Latched trip commands block capacitor step closing until the commands are reset $\boxed{14}$. Open commands must be at least as long as the duration of open and close control pulses.

### Capacitor Step Closing $\boxed{15}$
Close commands are always voluntary for manual and automatic control. They are as long as the duration of open and close control pulses.

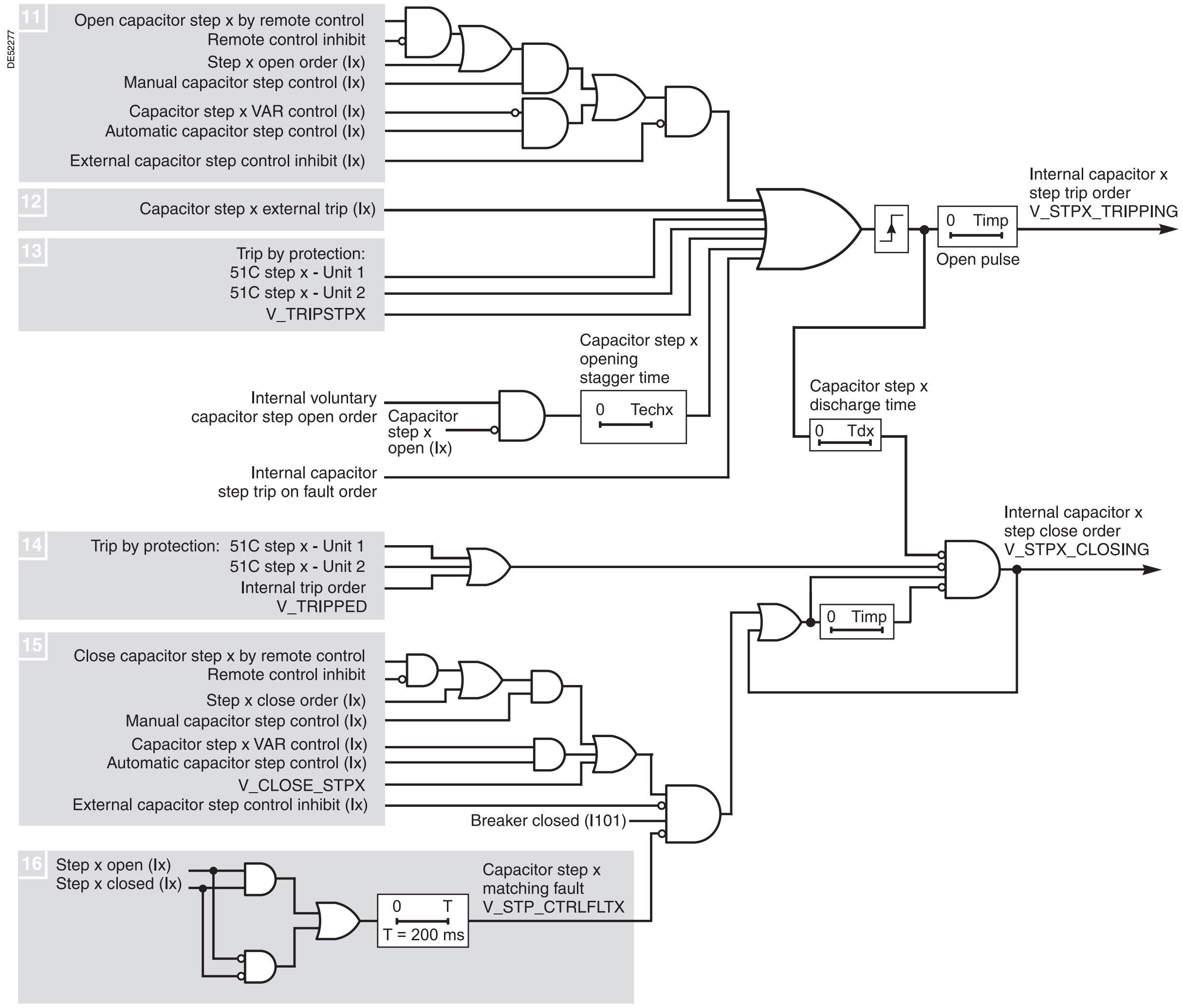
Capacitor step switches only close after the capacitor step discharge time delay has run out and after the circuit breaker has closed, if there is no protection fault or blocking.

### Capacitor Step Switch Matching Fault $\boxed{16}$
This function checks for capacitor step switch positions matching when the positions are set up on logic inputs (Ix).

In the event of a capacitor step switch matching fault, the switch close command is blocked.

# Capacitor Bank Switchgear Control
## ANSI Code 94/69

**Block Diagram**


DE52277
11
Open capacitor step x by remote control
Remote control inhibit
Step x open order (Ix)
Manual capacitor step control (Ix)
Capacitor step x VAR control (Ix)
Automatic capacitor step control (Ix)
External capacitor step control inhibit (Ix)
12
Capacitor step x external trip (Ix)
13
Trip by protection:
51C step x - Unit 1
51C step x - Unit 2
V_TRIPSTPX
Internal capacitor x
step trip order
V_STPX_TRIPPING
0 Timp
Open pulse
Capacitor step x
opening
stagger time
0 Techx
Internal voluntary
capacitor step open order
Capacitor
step x
open (Ix)
Internal capacitor
step trip on fault order
Capacitor step x
discharge time
0 Tdx
Internal capacitor x
step close order
V_STPX_CLOSING
14
Trip by protection: 51C step x - Unit 1
51C step x - Unit 2
Internal trip order
V_TRIPPED
0 Timp
15
Close capacitor step x by remote control
Remote control inhibit
Step x close order (Ix)
Manual capacitor step control (Ix)
Capacitor step x VAR control (Ix)
Automatic capacitor step control (Ix)
V_CLOSE_STPX
External capacitor step control inhibit (Ix)
Breaker closed (I101)
16
Step x open (Ix)
Step x closed (Ix)
0 T
T = 200 ms
Capacitor step x
matching fault
V_STP_CTRLFLTX

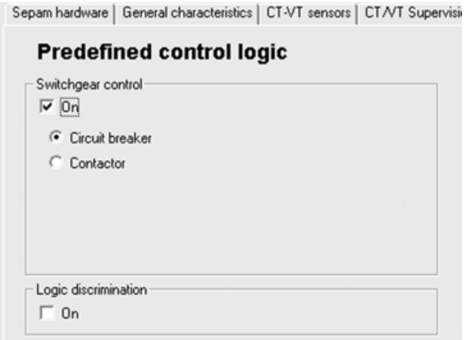
# Capacitor Bank Switchgear Control

ANSI Code 94/69

## Setting the Circuit Breaker Control Parameter

The function is set up and adapted to match the type of circuit breaker to be controlled using the SFT2841 software.

PE50456



Predefined control logic

Switchgear control

☑ On

● Circuit breaker

○ Contactor

Logic discrimination

☐ On

*SFT2841: Switchgear conrtol parameter setting*

**"Control Logic" Tab**

- activation of the Switchgear control function
- type of device to be controlled: Circuit breaker.

**"Logic I/Os" Tab**

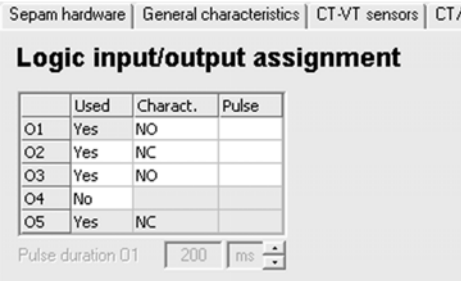
- assignment of the logic inputs required
- definition of logic output behavior.

By default, the following outputs are used:

| Logic Output | Associated Internal Command | Circuit Breaker Contacts |
|---|---|---|
| O1 | Trip<br>(V_TRIPPED) | Normally open (NO) |
| O2 | Close block<br>(V_CLOSE_BLOCKED) | Normally closed (NC) |
| O3 | Close<br>(V_CLOSED) | Normally open (NO) |

- the Trip command is always associated with output O1.
  If output O1 is set up for pulse type operation, the pulse command duration may be set up.
- the optional Close block and Close commands may be assigned to any logic output.

PE50455



Logic input/output assignment

| | Used | Charact. | Pulse |
|---|---|---|---|
| O1 | Yes | NO | |
| O2 | Yes | NC | |
| O3 | Yes | NO | |
| O4 | No | | |
| O5 | Yes | NC | |

Pulse duration O1 200 ms

*SFT2841: default parameter setting of logic outputs assigned to Switchgear control*

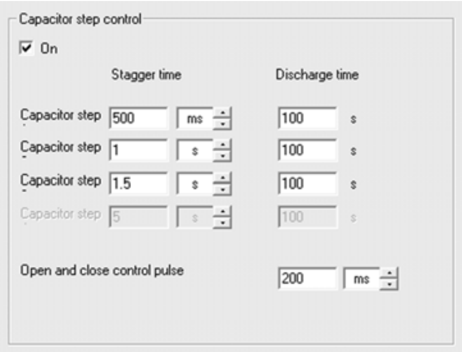
**"Matrix" Screen, "Logic" Button**

Modification of the default internal command assignment to outputs O2 and O3, if necessary.

## Setting the Capacitor Step Control Parameter

The function is set up and adapted using the SFT2841 software.

PE50457



Capacitor step control

☑ On

| | Stagger time | Discharge time |
|---|---|---|
| Capacitor step | 500 ms | 100 s |
| Capacitor step | 1 s | 100 s |
| Capacitor step | 1.5 s | 100 s |
| Capacitor step | 5 s | 100 s |

Open and close control pulse 200 ms

*SFT2841: Capacitor step control functionis parameter setting*

**"Particular Characteristics" Tab**

Setup of the capacitor bank, with setting of the number of steps.

**"Control Logic" Tab**

Setup of capacitor step control:

- activation of the Capacitor step control function
- setting of capacitor step staggered opening times, capacitor step discharge times and capacitor step switch control pulse duration.

**"Logic I/Os" Tab**

- assignment of the logic inputs required
- definition of the behavior of logic outputs assigned to capacitor step control

# Capacitor Bank Switchgear Control
ANSI Code 94/69

## Characteristics

| **Settings** | |
|---|---|
| **Switchgear Control** | |
| Setting range | On / Off |
| **Device Type** | |
| Setting range | Circuit breaker / Contactor |
| **Tripping Pulse Duration (Output O1)** | |
| Setting range | 200 ms to 300 s |
| Accuracy (1) | ±2% or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |
| **Control of Capacitor Banks** | |
| Setting range | On / Off |
| **Staggered Capacitor Step Opening Time Delay Techx (1 delay per step)** | |
| Setting range | 0 to 300 s |
| Accuracy (1) | ±2% or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |
| **Capacitor Step Discharge Time Delay Tdx (1 delay per step)** | |
| Setting range | 0 to 300 s |
| Accuracy (1) | ±2% or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |
| **Capacitor Step Open and Close Control Pulse Duration Timp** | |
| Setting range | 0 to 300 s |
| Accuracy (1) | ±2% or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Tripping, opening | V_TRIPCB | ■ | ■ |
| Block closing | V_BLOCKCLOSE | ■ | ■ |
| Closing | V_CLOSECB | ■ | ■ |
| Capacitor step 1 tripping | V_TRIP_STP1 | | ■ |
| Capacitor step 2 tripping | V_TRIP_STP2 | | ■ |
| Capacitor step 3 tripping | V_TRIP_STP3 | | ■ |
| Capacitor step 4 tripping | V_TRIP_STP4 | | ■ |
| Capacitor step 1 closing | V_CLOSE_STP1 | | ■ |
| Capacitor step 2 closing | V_CLOSE_STP2 | | ■ |
| Capacitor step 3 closing | V_CLOSE_STP3 | | ■ |
| Capacitor step 4 closing | V_CLOSE_STP4 | | ■ |

**Outputs**

| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Switchgear control on | V_SWCTRL_ON | | ■ | |
| Tripping, opening | V_TRIPPED | ■ | ■ | ■ |
| Block closing | V_BLOCK_CLOSE | ■ | ■ | ■ |
| Closing | V_CLOSED | ■ | ■ | ■ |
| Contactor control | V_CONTACTOR | | ■ | ■ |
| Capacitor bank control on | V_BANK_ON | | ■ | |
| Tripping of capacitor step 1 | V_STP1_TRIPPING | | ■ | ■ |
| Tripping of capacitor step 2 | V_STP2_TRIPPING | | ■ | ■ |
| Tripping of capacitor step 3 | V_STP3_TRIPPING | | ■ | ■ |
| Tripping of capacitor step 4 | V_STP4_TRIPPING | | ■ | ■ |
| Closing of capacitor step 1 | V_STP1_CLOSING | | ■ | ■ |
| Closing of capacitor step 2 | V_STP2_CLOSING | | ■ | ■ |
| Closing of capacitor step 3 | V_STP3_CLOSING | | ■ | ■ |
| Closing of capacitor step 4 | V_STP4_CLOSING | | ■ | ■ |
| Capacitor step 1 matching fault | V_STP1_CTRLFLT | | ■ | ■ |
| Capacitor step 2 matching fault | V_STP2_CTRLFLT | | ■ | ■ |
| Capacitor step 3 matching fault | V_STP3_CTRLFLT | | ■ | ■ |
| Capacitor step 4 matching fault | V_STP4_CTRLFLT | | ■ | ■ |

*(1) Under reference conditions (IEC 60255-6).*

# Latching/Acknowledgement

## Operation

The tripping outputs of all protection functions and logic inputs can be latched individually.

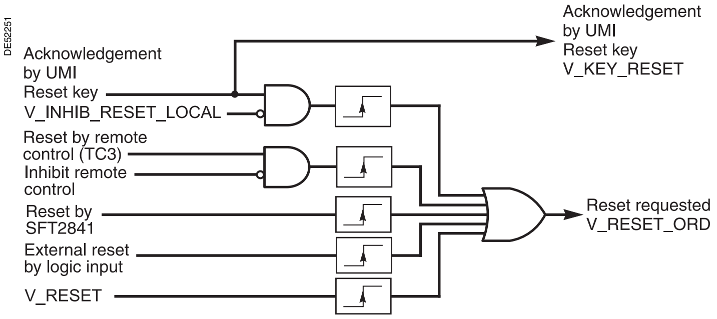
Logic outputs cannot be latched. Logic outputs set up as pulse-type outputs maintain pulse-type operation even when they are linked to latched data. Latched data is saved in the event of an auxiliary power loss

All latched data are acknowledged together, at the same time. Acknowledgement is done:

- locally on the UMI using the reset key
- or remotely via a logic input, the SFT2841 software or via the communication link
- or by logic equation or Logipam.

The remote indication TS5 remains present after latching operations until acknowledgement takes place. The Latching/acknowledgement function associated with the Switchgear control function can be used to perform the ANSI 86 Lockout relay function.

## Block Diagram


DE52251
Acknowledgement by UMI Reset key
V_INHIB_RESET_LOCAL
Reset by remote control (TC3)
Inhibit remote control
Reset by SFT2841
External reset by logic input
V_RESET
Acknowledgement by UMI Reset key V_KEY_RESET
Reset requested V_RESET_ORD

## Characteristics

**Inputs**

| Designation | Syntax | Equations | Logipam |
|---|---|---|---|
| Blocking UMI Reset key | V_BLOCK_RESET_LOCAL | ■ | ■ |
| Acknowledgement by logic equation or Logipam | V_RESET | ■ | ■ |

**Outputs**

| Designation | Syntax | Equations | Logipam | Matrix |
|---|---|---|---|---|
| Reset requested | V_RESET_ORD |  | ■ |  |
| Acknowledgement by UMI Reset key | V_KEY_RESET |  | ■ |  |

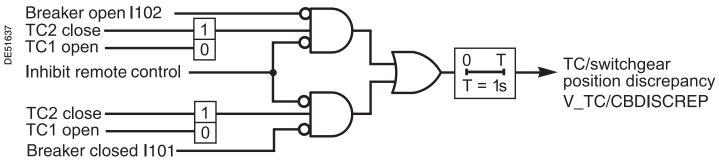
# TC/ Switchgear Position Discrepancy

## Operation

This function detects any discrepancy between the last remote control command received and the actual position of the circuit breaker or contactor.

The information is accessible in the matrix and via the remote indication TS3.

## Block Diagram


DE51637
Breaker open I102
TC2 close
TC1 open
1
0
Inhibit remote control
TC2 close
TC1 open
1
0
Breaker closed I101
0 T
T = 1s
TC/switchgear position discrepancy
V_TC/CBDISCREP

## Characteristics

| Outputs | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| TC/ switchgear position discrepancy | V_TC/CBDISCREP | | ■ | |

# Disturbance-Recording Trigger

## Operation

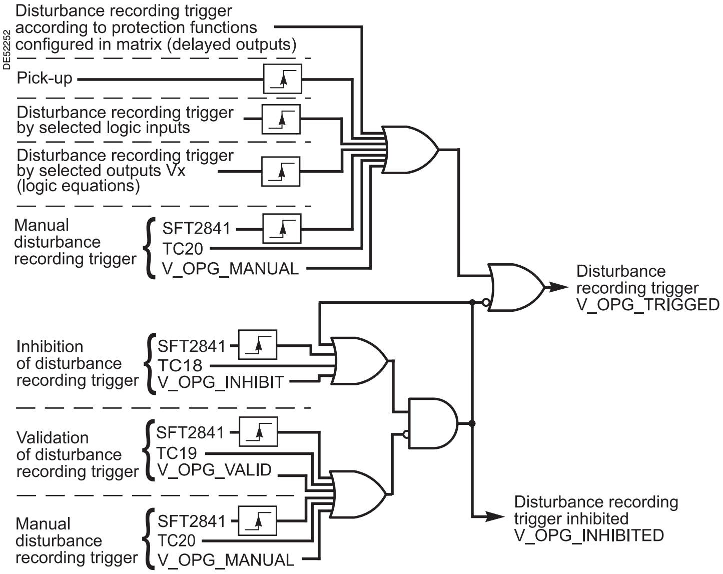
Recording analog and logic signals can be triggered by different events, according to control matrix parameter setting or by manual action:

- triggering by the grouping of all pick-up signals of the protection functions in service
- triggering by the delayed outputs of selected protection functions
- triggering by selected logic inputs
- triggering by selected outputs Vx (logic equations)
- manual triggering by a remote control command (TC20)
- manual triggering via the SFT2841 software tool
- manual triggering by Logipam

Disturbance recording can be:

- blocked by SFT2841 software, remote control command (TC18), or Logipam
- validated by SFT2841 software, remote control command (TC19), or by Logipam

## Block Diagram


DE52252
Disturbance recording trigger according to protection functions configured in matrix (delayed outputs)
Pick-up
Disturbance recording trigger by selected logic inputs
Disturbance recording trigger by selected outputs Vx (logic equations)
Manual disturbance recording trigger
SFT2841
TC20
V_OPG_MANUAL
Disturbance recording trigger V_OPG_TRIGGED
Inhibition of disturbance recording trigger
SFT2841
TC18
V_OPG_INHIBIT
Validation of disturbance recording trigger
SFT2841
TC19
V_OPG_VALID
Manual disturbance recording trigger
SFT2841
TC20
V_OPG_MANUAL
Disturbance recording trigger inhibited V_OPG_INHIBITED

## Characteristics

| **Inputs** | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Blocks disturbance recording function | V_OPG_BLOCK | | ■ | |
| Validates disturbance recording function | V_OPG_VALID | | ■ | |
| Manual trigger of disturbance recording function | V_OPG_MANUAL | | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Disturbance recording function triggered | V_OPG_TRIGGED | | ■ | |
| Disturbance recording function blocked | V_OPG_BLOCKED | | ■ | ■ |
| Disturbance recording on | V_OPG_ON | | ■ | |

# Switching Groups of Settings

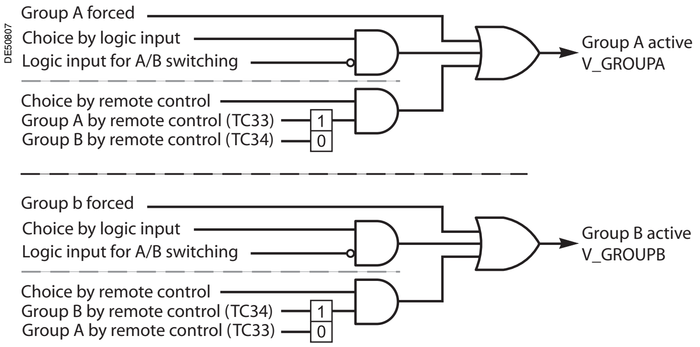
## Operation

There are two groups of settings, A and B, for the phase overcurrent, ground fault, directional phase overcurrent and directional ground fault protection functions. Switching from one group to another makes it possible to adapt the protection characteristics to suit the electrical environment of the application (change of grounding system, changeover to local power generation). Switching settings is global and applies to all the units of the protection functions mentioned above.

The groups of settings switching mode is determined by parameter setting:

- switching according to the position of a logic input (0 = group A, 1 = group B)
- switching by remote control command (TC33, TC34)
- forced group A or group B.

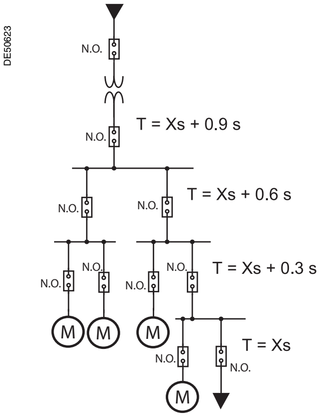
## Block Diagram


DE50807
Group A forced
Choice by logic input
Logic input for A/B switching
Choice by remote control
Group A by remote control (TC33)
Group B by remote control (TC34)
1
0
Group A active
V_GROUPA
Group b forced
Choice by logic input
Logic input for A/B switching
Choice by remote control
Group B by remote control (TC34)
Group A by remote control (TC33)
1
0
Group B active
V_GROUPB

## Characteristics

| **Outputs** | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Group of settings A active | V_GROUPA | | ■ | |
| Group of settings B active | V_GROUPB | | ■ | |

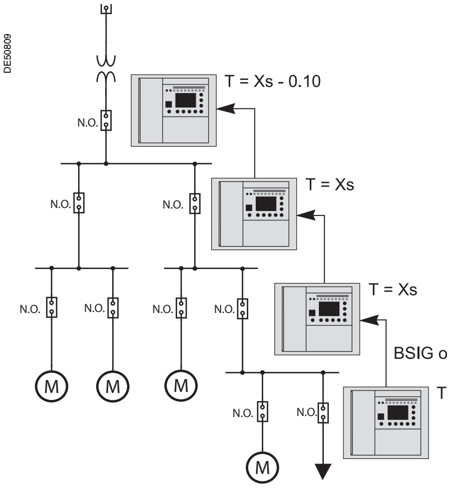
# Zone Selective Interlocking
Principle



*Example: radial distribution with use of time-based discrimination (T: protection setting time. As an approximation for definite time curves, this is assumed to be equal to the protection tripping time).*

*The upstream protection units are typically delayed by 0.3 s to give the downstream protection units time to trip. When there are many levels of discrimination, the fault clearing time at the source is long.*

*In this example, if the fault clearing time for the protection unit furthest downstream is Xs = 0.2 s, the fault clearing time at the source is T = Xs + 0.9 s = 1.1 s*



*Example: radial distribution with use of zone selective interlocking*
*(T: protection setting time. As an approximation for definite time curves, this is assumed to be equal to the protection tripping time).*
*When a fault appears, the protection units that detect it block the upstream protection units. The protection unit furthest downstream trips since it is not blocked by another protection unit. The delays are to be set in accordance with the device to be protected.*
*In this example, if the fault clearing time for the protection device furthest downstream is Xs = 0.2 s, the fault clearing time at the source is T = Xs - 0.1 s = 0.1 s.*

## Operation

This function significantly reduces the tripping time of the circuit breakers closest to the source. It can be used for zone selective interlocking (ZSI) in closed ring networks. It applies to the phase overcurrent 50/51, directional phase overcurrent 67, ground fault 50N/51N and directional ground fault 67N protection functions, definite time and IDMT.

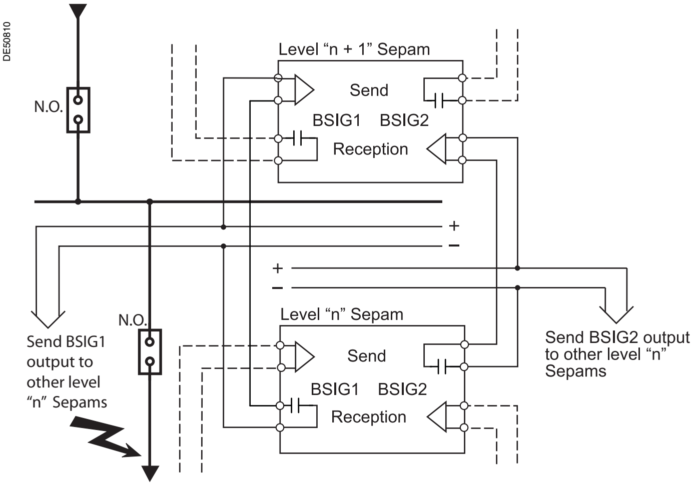
Sepam™ Series 80 ZSI logic includes two logic groups. Each group includes:
- logic thresholds: protection units that send blocking signals (BSIG) and may be prevented from tripping by the reception of blocking signals.
- time-based thresholds: protection units that may not be prevented from tripping by blocking signals and do not send blocking signals. They are used as backup for the logic thresholds.

When a fault occurs:
- the logic thresholds detecting the fault send blocking signals upstream
- the logic thresholds detecting the fault send a tripping command if they are not blocked by blocking signals
- the time-based (backup) thresholds detecting the fault send a tripping command

The logic and time-based threshold assignments of the protection units depend on the type of application and the parameter setting of the logic inputs/outputs.
The first logic group is active if one of the following two conditions is met:
- blocking reception **1** is assigned to a logic input Ixxx, except for motors which do not have this input.
- blocking send **1** is assigned to an output Oxxx. (O102 by default).

When the second logic group is present in the application, it is active under one of the following two conditions:
- blocking reception **2** is assigned to a logic input Ixxx
- blocking send **2** is assigned to an output Oxxx (O103 by default).

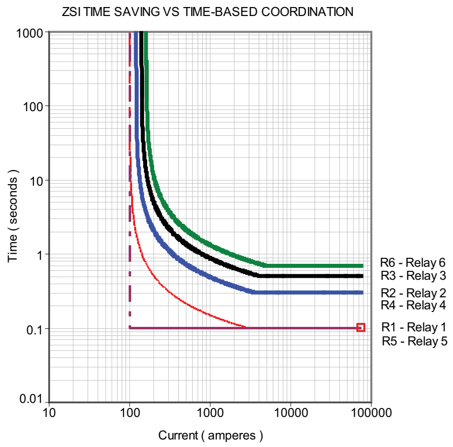
The SFT 2841 software indicates the type of threshold, logic or time-based, according to the input/output parameter setting.



Assigning protection devices to the two ZSI groups is fixed and cannot be modified. When ZSI is used, it is important to ensure that the measurement origin and logic group to which the unit is assigned are in accordance.

By default, the same logic group has the same measurement origin. When several origins are possible, the main channels Ia, Ib, Ic and Ir are assigned by default to the first group and the additional channels I'a, I'b, I'c, I'r to the second.

# Zone Selective Interlocking
## Principle



The duration of blocking signals lasts as long as it takes to clear the fault. If Sepam™ issues a tripping command, the blocking signals are interrupted after a time delay that takes into account the breaking device operating time and the protection unit reset time. This system guarantees safety in downgraded operating situations (faulty wiring or switchgear).

### Pilot Wire Test

Use the output relay test function in the SFT2841 software to test the pilot wires that carry interlocks between breaker/relay functions.

# Zone Selective Interlocking
S80, S81, T81, B80, and B83 Applications

## Threshold Assignment

| Type of Protection | Unit Number Time-Based | Send Logic | | Reception Logic | |
|---|---|---|---|---|---|
| | | Group 1 | Group 2 | Group 1 | Group 2 |
| **50/51** | 3, 4, 5, 6, 7, 8 | 1, 2 | - | 1, 2 | - |
| **50N/51N** | 3, 4, 5, 6, 7, 8 | 1, 2 | - | 1, 2 | - |
| **67N** | 2 | 1 | - | 1 | - |

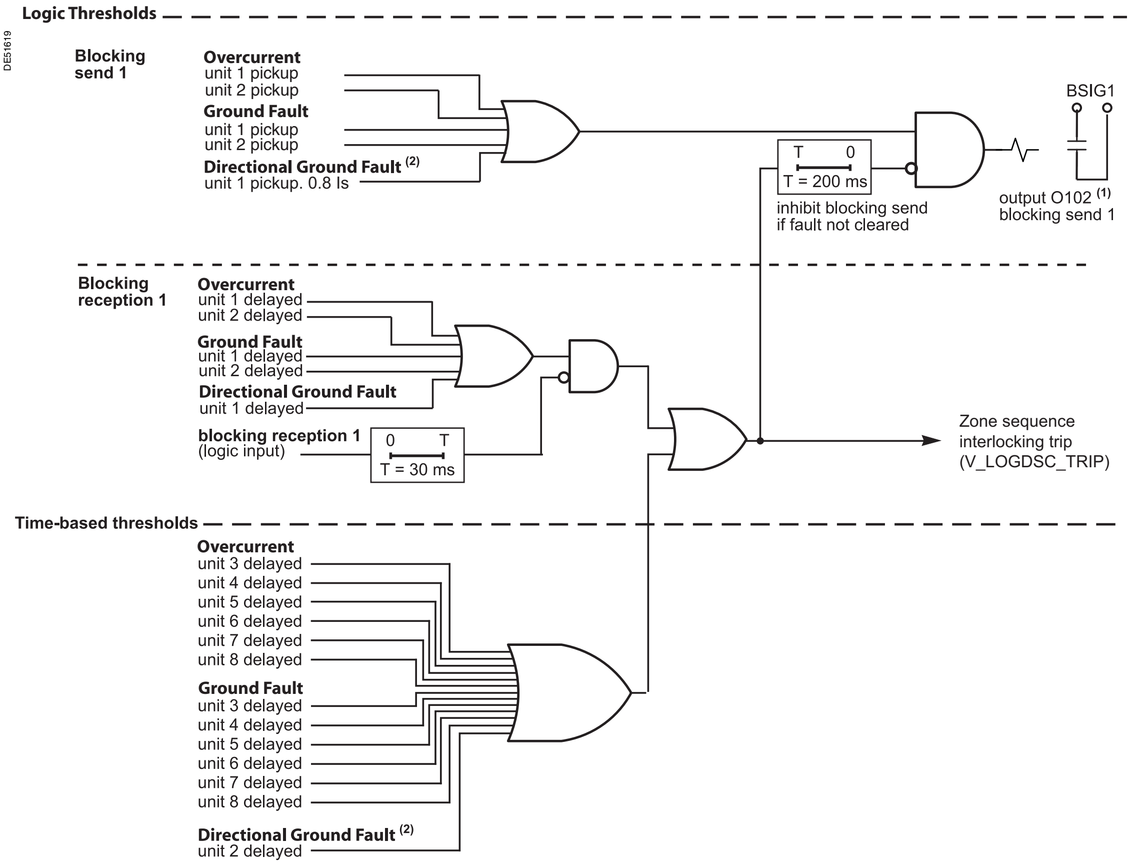
***(1)*** *According to application.*

## Characteristics

| Settings | | | | |
|---|---|---|---|---|
| **Activity** | | | | |
| Setting range | On / Off | | | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Zone selective Interlocking trip | V_LOGDSC_TRIP | ■ | ■ | ■ (1) |
| Blocking send 1 | V_LOGDSC_BL1 | ■ | ■ | ■ |
| Zone selective Interlocking on | V_LOGDSC_ON | | ■ | |

***(1)*** *Only if switchgear control is not in service.*

## Block Diagram


DE51619
Logic Thresholds
Blocking send 1
Overcurrent
unit 1 pickup
unit 2 pickup
Ground Fault
unit 1 pickup
unit 2 pickup
Directional Ground Fault (2)
unit 1 pickup. 0.8 Is
T 0
T = 200 ms
inhibit blocking send if fault not cleared
BSIG1
output O102 (1)
blocking send 1
Blocking reception 1
Overcurrent
unit 1 delayed
unit 2 delayed
Ground Fault
unit 1 delayed
unit 2 delayed
Directional Ground Fault
unit 1 delayed
blocking reception 1
(logic input)
0 T
T = 30 ms
Zone sequence interlocking trip (V_LOGDSC_TRIP)
Time-based thresholds
Overcurrent
unit 3 delayed
unit 4 delayed
unit 5 delayed
unit 6 delayed
unit 7 delayed
unit 8 delayed
Ground Fault
unit 3 delayed
unit 4 delayed
unit 5 delayed
unit 6 delayed
unit 7 delayed
unit 8 delayed
Directional Ground Fault (2)
unit 2 delayed

***(1)*** *By default.*
***(2)*** *According to application.*

# Zone Selective Interlocking
M81, M87, M88, and C86
Applications

## Threshold Assignment

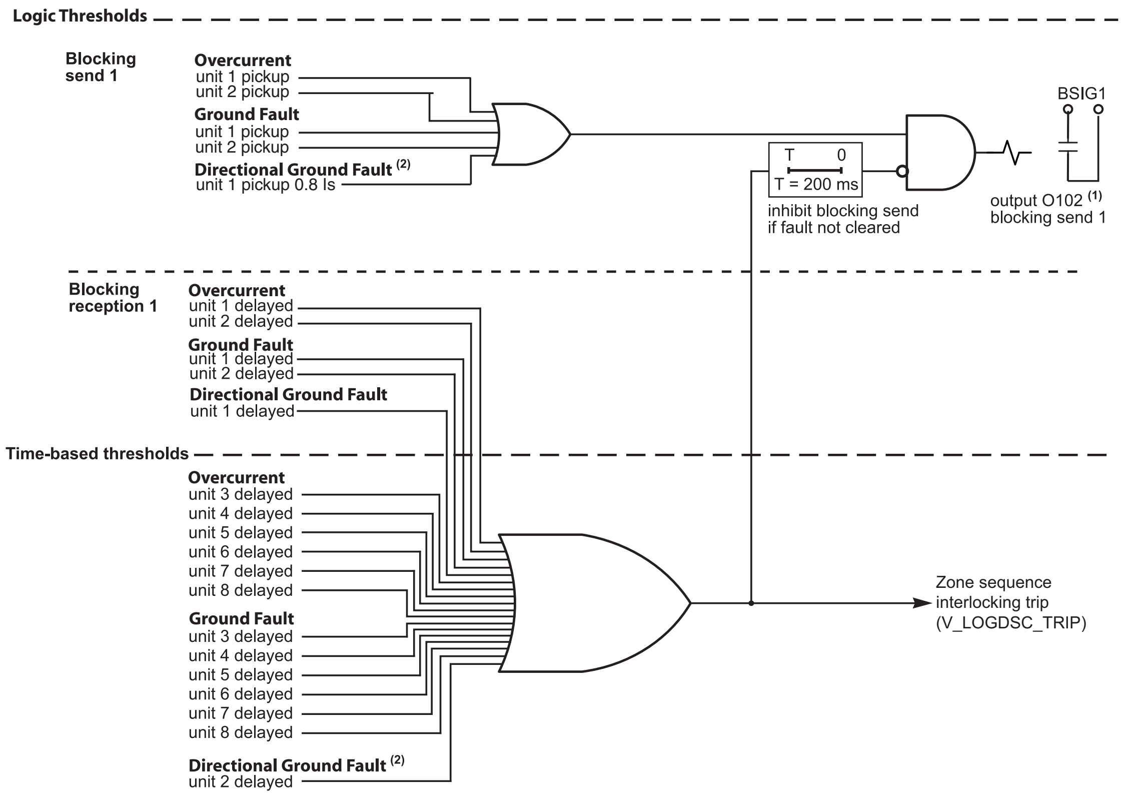
| Type of Protection | Unit Number<br>Time-Based | Send Logic | | Reception Logic | |
|---|---|---|---|---|---|
| | | Group 1 | Group 2 | Group 1 | Group 2 |
| **50/51** | 3, 4, 5, 6, 7, 8 | 1, 2 | - | - | - |
| **50N/51N** | 3, 4, 5, 6, 7, 8 | 1, 2 | - | - | - |
| **67N** | 2 | 1 | - | - | - |

## Characteristics

| **Settings** | | | | |
|---|---|---|---|---|
| **Activity** | | | | |
| Setting range | On / Off | | | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Zone selective Interlocking trip | V_LOGDSC_TRIP | | ■ | ■ (1) |
| Blocking send 1 | V_LOGDSC_BL1 | | ■ | ■ |
| Zone selective Interlocking on | V_LOGDSC_ON | | ■ | |

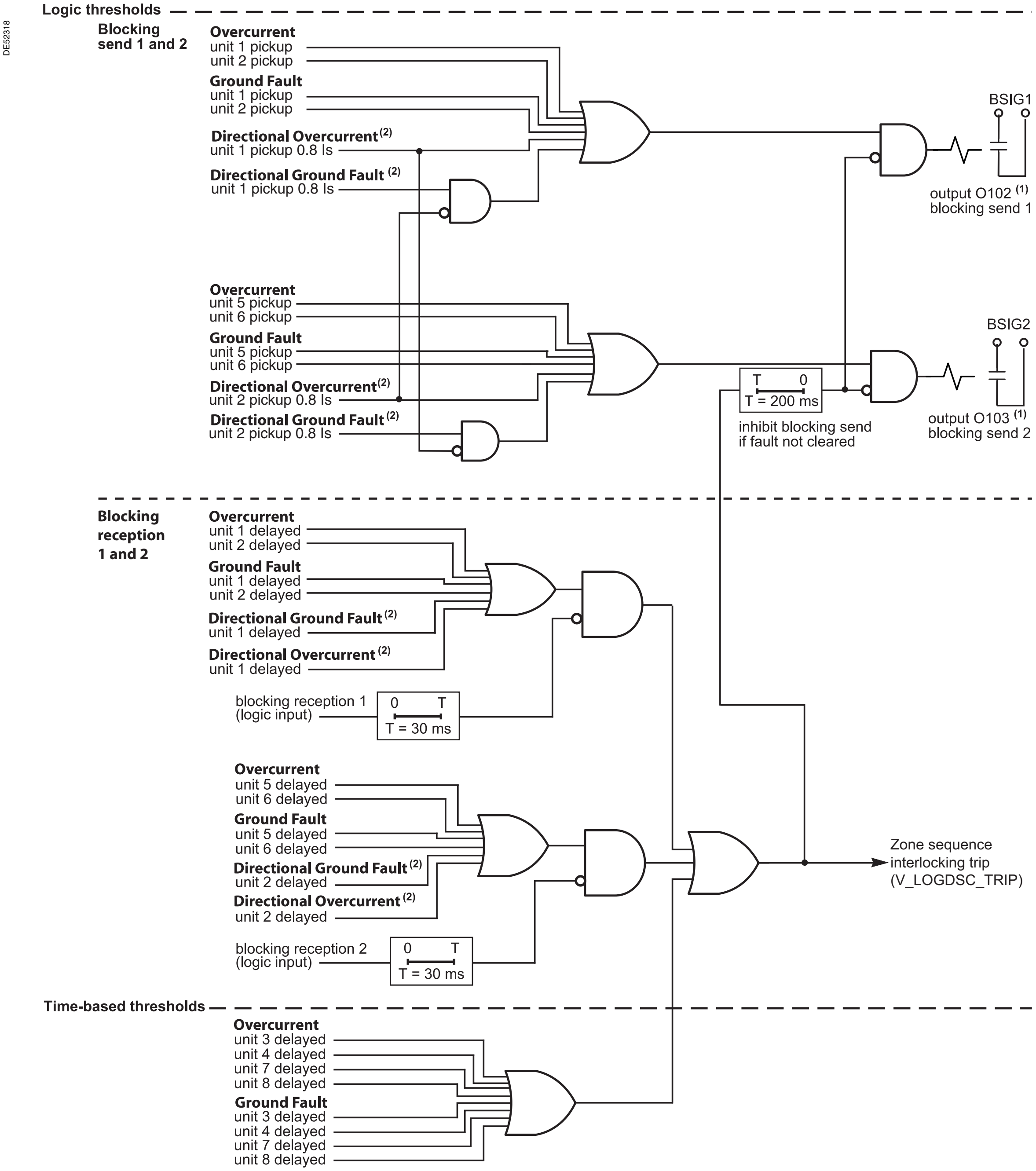
**(1)** *Only if switchgear control is not in service.*

## Block Diagram


DE51620
Logic Thresholds
Blocking send 1
Overcurrent
unit 1 pickup
unit 2 pickup
Ground Fault
unit 1 pickup
unit 2 pickup
Directional Ground Fault (2)
unit 1 pickup 0.8 Is
T 0
T = 200 ms
inhibit blocking send
if fault not cleared
BSIG1
output O102 (1)
blocking send 1
Blocking reception 1
Overcurrent
unit 1 delayed
unit 2 delayed
Ground Fault
unit 1 delayed
unit 2 delayed
Directional Ground Fault
unit 1 delayed
Time-based thresholds
Overcurrent
unit 3 delayed
unit 4 delayed
unit 5 delayed
unit 6 delayed
unit 7 delayed
unit 8 delayed
Ground Fault
unit 3 delayed
unit 4 delayed
unit 5 delayed
unit 6 delayed
unit 7 delayed
unit 8 delayed
Directional Ground Fault (2)
unit 2 delayed
Zone sequence
interlocking trip
(V_LOGDSC_TRIP)

# Zone Selective Interlocking
## S82, S84, T82, T87, G82, G87, and G88 Applications

### Block Diagram


DE52318
Logic thresholds
Blocking send 1 and 2
Overcurrent
unit 1 pickup
unit 2 pickup
Ground Fault
unit 1 pickup
unit 2 pickup
Directional Overcurrent (2)
unit 1 pickup 0.8 Is
Directional Ground Fault (2)
unit 1 pickup 0.8 Is
BSIG1
output O102 (1)
blocking send 1
Overcurrent
unit 5 pickup
unit 6 pickup
Ground Fault
unit 5 pickup
unit 6 pickup
Directional Overcurrent (2)
unit 2 pickup 0.8 Is
Directional Ground Fault (2)
unit 2 pickup 0.8 Is
T 0
T = 200 ms
inhibit blocking send
if fault not cleared
BSIG2
output O103 (1)
blocking send 2
Blocking reception 1 and 2
Overcurrent
unit 1 delayed
unit 2 delayed
Ground Fault
unit 1 delayed
unit 2 delayed
Directional Ground Fault (2)
unit 1 delayed
Directional Overcurrent (2)
unit 1 delayed
blocking reception 1
(logic input)
0 T
T = 30 ms
Overcurrent
unit 5 delayed
unit 6 delayed
Ground Fault
unit 5 delayed
unit 6 delayed
Directional Ground Fault (2)
unit 2 delayed
Directional Overcurrent (2)
unit 2 delayed
blocking reception 2
(logic input)
0 T
T = 30 ms
Zone sequence
interlocking trip
(V_LOGDSC_TRIP)
Time-based thresholds
Overcurrent
unit 3 delayed
unit 4 delayed
unit 7 delayed
unit 8 delayed
Ground Fault
unit 3 delayed
unit 4 delayed
unit 7 delayed
unit 8 delayed

**(1)** *By default.*
**(2)** *According to application.*

# **Zone Selective Interlocking**
# S82, S84, T82, T87, G82, G87, and G88 Applications

## Threshold Assignment

| Type of Protection | Unit Number |  |  |  |  |
|---|---|---|---|---|---|
|  | Time-Based | Send Logic |  | Reception Logic |  |
|  |  | Group 1 | Group 2 | Group 1 | Group 2 |
| **50/51** | 3, 4, 7, 8 | 1, 2 | 5, 6 | 1, 2 | 5, 6 |
| **50N/51N** | 3, 4, 7, 8 | 1, 2 | 5, 6 | 1, 2 | 5, 6 |
| **67 (1)** | - | 1 | 2 | 1 | 2 |
| **67N (1)** | - | 1 | 2 | 1 | 2 |

***(1)** According to application.*

## Characteristics

| **Settings** |  |  |  |  |
|---|---|---|---|---|
| **Activity** |  |  |  |  |
| Setting range | On / Off |  |  |  |
| **Outputs** |  |  |  |  |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Zone selective Interlocking trip | V_LOGDSC_TRIP |  | ■ | ■ (1) |
| Blocking send 1 | V_LOGDSC_BL1 |  | ■ | ■ |
| Blocking send 2 | V_LOGDSC_BL2 |  | ■ | ■ |
| Zone selective Interlocking on | V_LOGDSC_ON |  | ■ |  |

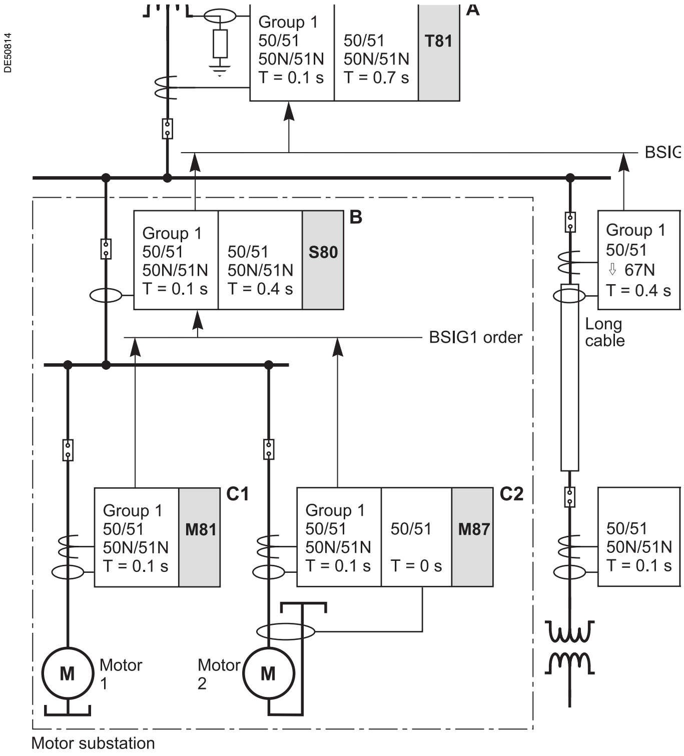
***(1)** Only if switchgear control is not in service.*

# Zone Selective Interlocking
## Example: Radial Network

When a fault occurs in a radial network, the fault current flows through the circuit between the source and the location of the fault: The protection units upstream from the fault are triggered. The protection units downstream from the fault are not triggered. Only the first protection unit upstream from the fault should trip.

**Example of Setting**

A 20 kV installation, supplied by a transformer, comprises the main bus which in turn supply a feeder to a motor substation and a long feeder to a distant MV/LV transformer. The installation is grounded via a resistor at the incoming transformer neutral point, which limits the current to about 10 Amps.


DE50814
A
Group 1
50/51
50N/51N
T = 0.1 s
50/51
50N/51N
T = 0.7 s
T81
BSIG
B
Group 1
50/51
50N/51N
T = 0.1 s
50/51
50N/51N
T = 0.4 s
S80
Group 1
50/51
⇩ 67N
T = 0.4 s
BSIG1 order
Long cable
C1
Group 1
50/51
50N/51N
T = 0.1 s
M81
C2
Group 1
50/51
50N/51N
T = 0.1 s
50/51
T = 0 s
M87
50/51
50N/51N
T = 0.1 s
M
Motor 1
Motor 2
M
Motor substation

⇧ *: direction of protection function detection*

▲ *: direction of blocking signal orders*

# Zone Selective Interlocking
## Example: Radial Network

Based on a network coordination study, the installation relay settings are as follows:
- main: Sepam™ T81 (relay A)
  - ☐ bus fault thresholds
    50/51, 50N/51N: T =0.1 s (DT)

Zone selective Interlocking group 1:
    - blocked by relays B and D
    - blocking send 1 to high voltage relays
  - ☐ backup thresholds

50/51, 50N/51N: T = 0.7 s (DT)
Time-based thresholds
- feeder to motor substation: Sepam™ S80 (relay B)
  - ☐ bus fault thresholds

50/51, 50N/51N: T = 0.1 s (DT)
Zone selective Interlocking group 1:
    - blocked by relays C1 and C2
    - blocking send 1 to relay A
  - ☐ backup thresholds

50/51, 50N/51N: T = 0.4 s (DT)
Time-based thresholds
- motor feeders:
- motor 1: Sepam™ M81 (relay C1)
  - ☐ motor fault thresholds

50/51, 50N/51N: T = 0.1 s (DT)
Zone selective Interlocking group 1:
    - blocking send 1 to relay B
- motor 2: Sepam™ M87 (relay C2)
  - ☐ motor fault thresholds
    - 50/51, 50N/51N: T = 0.1 s (DT)

Zone selective Interlocking group 1: blocking send 1 to relay B
Measurement origin: Ia, Ib, Ic
    - 50/51 self-balancing differential scheme: T =0s (DT)

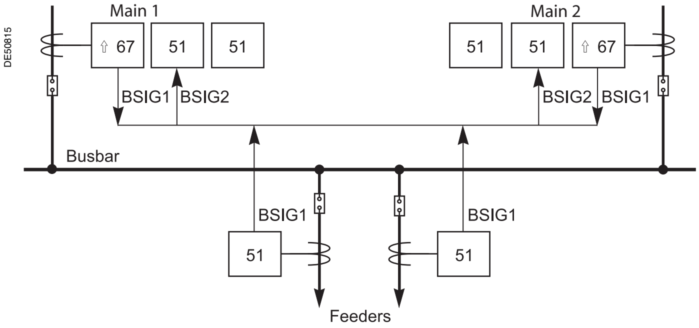
Time-based threshold
Measurement origin: I'a, I'b, I'c
- transformer feeder
  - ☐ cable fault thresholds

50/51, 67N: T = 0.4 s (DT)
Zone selective Interlocking group 1:
    - these thresholds are set time-wise in relation to relay E
    - blocking send 1 to relay A.

The logic input and output settings for all the relays concerned are:
- blocking reception 1 on I103
- blocking send 1 on O102.

# Zone Selective Interlocking
## Example: Parallel Mains

Substations supplied by two (or more) parallel mains may be protected using Sepam™ S82, T82, or G82, by a combination of directional phase (67) and ground fault (67N) protection functions, with the zone selective interlocking function.



⇧ *: direction of protection function detection*

▲ *: direction of blocking signal orders*

To avoid both mains tripping when a fault occurs upstream from one main, the main protection devices must operate as follows:

- protection function 67 of the faulty main detects the fault current in the "line" direction, the protection tripping direction:
  - sends a blocking signal to block the phase overcurrent protection functions (50/51) of both mains
  - and initiates tripping of the main circuit breaker
- protection function 67 of the fault-free main is insensitive to fault current in the "bus" direction.

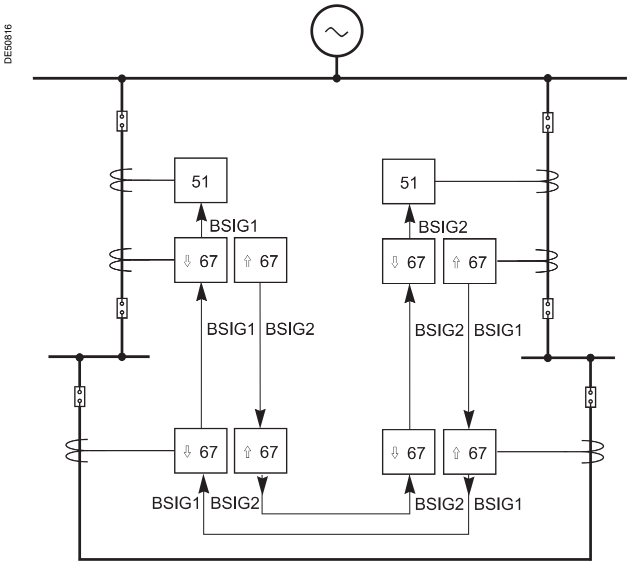
### Example of Setting

- logic input / output assignment:
  - I104: blocking reception 2 - **Do not assign any inputs to blocking reception 1**
  - O102: blocking send 1
- protection function 67 unit 1: tripping direction = line
  - instantaneous output: blocking send 1
  - delayed output: not blocked (no input assigned to blocking signal 1), circuit breaker tripping on faults upstream from main
- protection function 50/51, unit 5:
  - delayed output:
    - blocked by protection 67, unit 1 if there is a fault upstream from the main
    - not blocked for bus faults
    - blocked for feeder faults
- protection function 50/51, unit 3 as backup.

# Zone Selective Interlocking
## Example: Closed Ring Network

Closed ring network protection may be provided by Sepam™ S82 or T82. This includes the following functions:

- two units of directional phase (67) and ground fault (67N) protection functions:
  - ☐ one unit to detect faults in the "line" direction
  - ☐ one unit to detect faults in the "bus" direction
- use of two discrimination groups:
  - ☐ sending two blocking signals according to the detected fault direction
  - ☐ receiving two blocking signals to block the directional protection relays according to the detection direction.



*⇧, ⇩ : direction of protection function detection*

*: direction of blocking signal orders*

With the combination of directional protection functions and the zone selective interlocking function, the faulty section may be isolated with a minimal delay by tripping of the circuit breakers on either side of the fault.

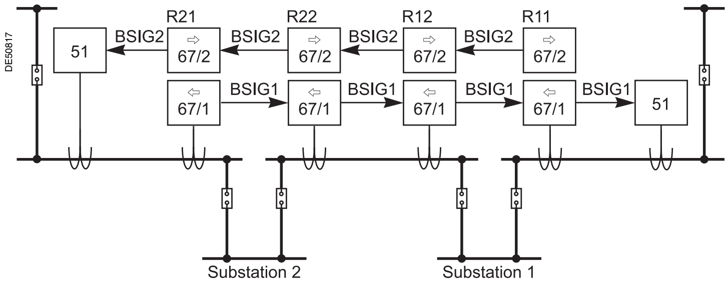
Blocking signals are initiated by both protection functions 67 and 67N. Priority is given to protection function 67: when protection functions 67 and 67N detect faults in opposite directions at the same time, the blocking signal sent is determined by the direction of the fault detected by protection function 67.

The instantaneous output of protection functions 67 and 67N, activated at 80% of the Is threshold, is used to send blocking signals. This avoids uncertainty when the fault current is close to the Is threshold.

# Zone Selective Interlocking
## Example: Closed Ring Network

**Example:**

Case of a closed ring with two substations, each of which comprises two Sepam™ S82 relays, marked R11, R12 and R21, R22.



⇨, ⇦ : *direction of protection function detection*
↑ : *direction of blocking signal orders*

Starting at one end of the ring, the detection direction of units 1 and 2 of the directional protection functions should be alternated between line and bus.

Example of setting of the different Sepam™ relays linked to zone selective interlocking:

| **Substation 1** | |
|---|---|
| **Sepam™ S82 No. R11** | **Sepam™ S82 No. R12** |
| ■ Logic input/output assignment:<br>I103: blocking reception 1<br>O102: blocking send 1<br>O103: blocking send 2 | ■ Logic input/output assignment:<br>I103: blocking reception 1<br>I104: blocking reception 2<br>O102: blocking send 1<br>O103: blocking send 2 |
| ■ 67, 67N, unit 1:<br>tripping direction = bus<br>■ 67, 67N, unit 2:<br>tripping direction = line | ■ 67, 67N, unit 1:<br>tripping direction = line<br>■ 67, 67N, unit 2:<br>tripping direction = bus |
| **Substation 2** | |
| **Sepam™ S82 No. R22** | **Sepam™ S82 No. R21** |
| ■ Logic input/output assignment:<br>I103: blocking reception 1<br>I104: blocking reception 2<br>O102: blocking send 1<br>O103: blocking send 2 | ■ Logic input/output assignment:<br>I103: blocking reception 1<br>O102: blocking send 1<br>O103: blocking send 2 |
| ■ 67, 67N, unit 1:<br>tripping direction = bus<br>■ 67, 67N, unit 2:<br>tripping direction = line | ■ 67, 67N, unit 1:<br>tripping direction = line<br>■ 67, 67N, unit 2:<br>tripping direction = bus |

# Load Shedding

## Operation

The purpose of load shedding is to reduce the load on the electrical network in order to keep the voltage within an acceptable range.
Load shedding may be triggered by:

- a command from outside Sepam™ in the presence of a logic input assigned for the reception of load shedding commands. Commands can be delayed
- a voltage dip detected by the delayed output of Sepam™ 27D protection unit 1 (typical setting 40% $V_{LL}N$).

Load shedding triggers:

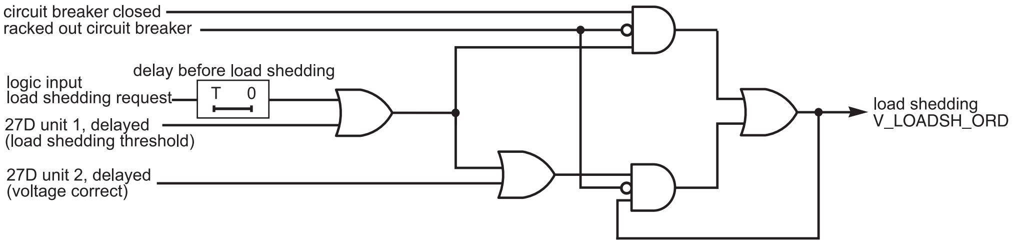
- tripping by the switchgear control function
- Block closing as long as the load shedding command is maintained.

The load shedding command is maintained as long as one of the following three conditions is present:

- external command via logic input
- positive sequence voltage detected by 27D unit 1 less than load shedding voltage threshold
- insufficient positive sequence voltage detected by the delayed 27D unit 2 for a restart command to be given . The time delay for the detection of correct voltage recovery must be shorter than the load shedding delay (27D unit 1) in order for the load shedding command to be maintained correctly. This unit is also used by the restart function.

The function may be validated by the switchgear closed and not racked out conditions.

## Block Diagram


DE51607
circuit breaker closed
racked out circuit breaker
delay before load shedding
logic input
load shedding request
T 0
27D unit 1, delayed
(load shedding threshold)
27D unit 2, delayed
(voltage correct)
load shedding
V_LOADSH_ORD

## Characteristics

| Settings | | | | |
|---|---|---|---|---|
| **Activity** | | | | |
| Setting range | On / Off | | | |
| **Delay Before Load Shedding** | | | | |
| Setting range | 0 to 300 s | | | |
| Accuracy [(1)] | ±2% or from –10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Load shedding command | V_LOADSH_ORD | | ■ | ■ |
| Load shedding on | V_LOADSH_ON | | ■ | |

*(1) Under reference conditions (IEC 60255-6).*

# Motor Auto-Restart

## Operation

This function enables motors to be automatically restarted after a shutdown caused by load shedding. It allows staggered restarting of process motors, as long as the voltage dip that caused load shedding was brief.

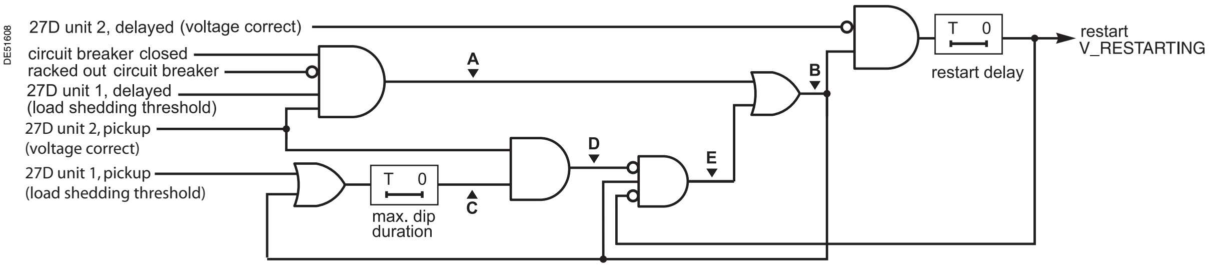
When tripping occurs due to a dip in the network supply voltage detected by 27D protection unit 1, two outcomes are possible:

- the voltage dip lasts for a period longer than the maximum voltage dip duration: tripping is final. External action is required for restart (see example 2).
- the voltage dip lasts for a period shorter than the maximum dip duration: a restart command is given. Delayed restart allows motor restart commands to be staggered to avoid network overload (see example 3).

Enabling restart is detected after the delayed output of protection 27D unit 2 drops out. This threshold allows the return of voltage to be detected independently with respect to the load shedding threshold. The typical setting is 50% $V_{LL}N$.

The restart command is given by the switchgear control function.

## Block Diagram


DE51608
27D unit 2, delayed (voltage correct)
circuit breaker closed
racked out circuit breaker
27D unit 1, delayed
(load shedding threshold)
27D unit 2, pickup
(voltage correct)
27D unit 1, pickup
(load shedding threshold)
T 0
max. dip
duration
A
B
C
D
E
T 0
restart delay
restart
V_RESTARTING

## Characteristics

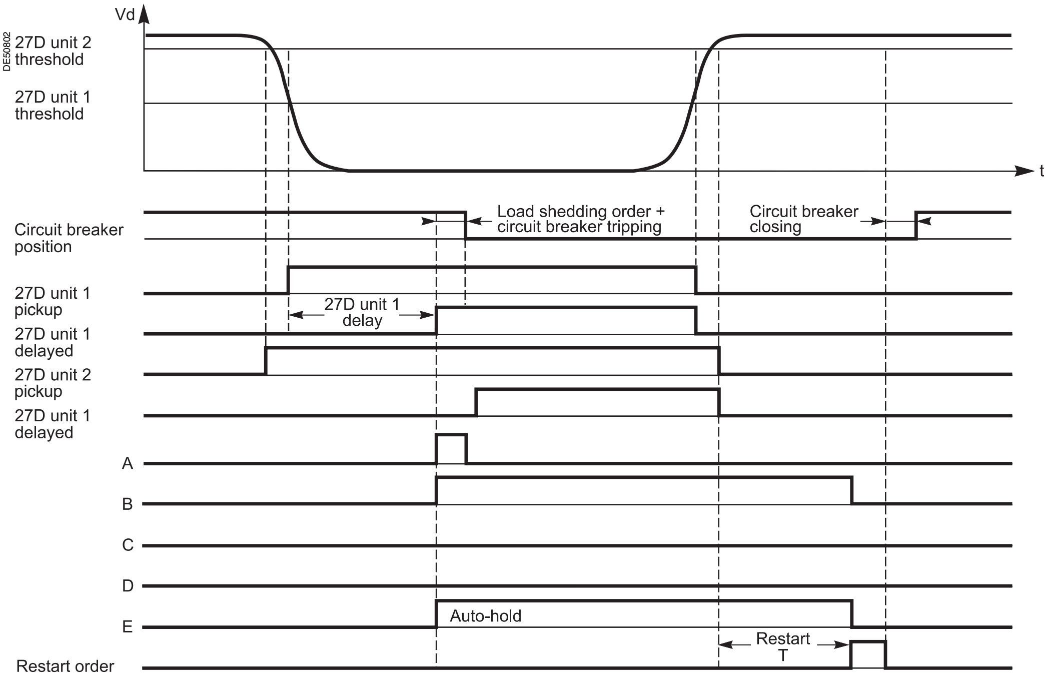
| **Settings** | |
|---|---|
| **Activity** | |
| Setting range | On / Off |
| **Maximum Voltage Dip Duration** | |
| Setting range | 0 to 300 s |
| Accuracy [(1)] | ±2% or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |
| **Restart Delay** | |
| Setting range | 0 to 300 s |
| Accuracy [(1)] | ±2% or from –10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |

**Outputs**

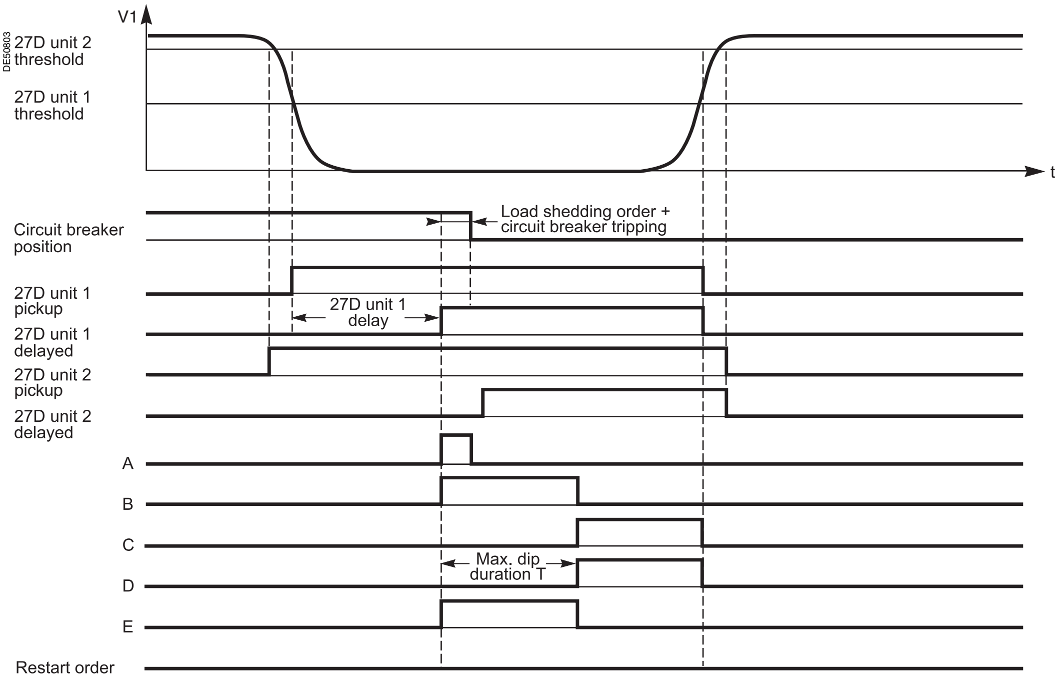
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
|---|---|---|---|---|
| Restart command | V_RESTARTING | | ■ | |
| Restart on | V_RESTART_ON | | ■ | |

***(1)** Under reference conditions (IEC 60255-6).*

### Example 1: Voltage Dip with Restart Command


DE50802
Vd
27D unit 2 threshold
27D unit 1 threshold
t
Circuit breaker position
Load shedding order + circuit breaker tripping
Circuit breaker closing
27D unit 1 pickup
27D unit 1 delay
27D unit 1 delayed
27D unit 2 pickup
27D unit 1 delayed
A
B
C
D
E
Auto-hold
Restart T
Restart order

### Example 2: Voltage Dip without Restart Command

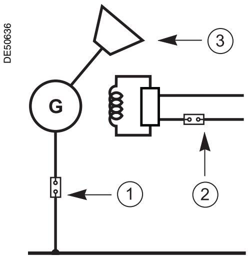

DE50803
V1
27D unit 2 threshold
27D unit 1 threshold
t
Circuit breaker position
Load shedding order + circuit breaker tripping
27D unit 1 pickup
27D unit 1 delay
27D unit 1 delayed
27D unit 2 pickup
27D unit 2 delayed
A
B
C
Max. dip duration T
D
E
Restart order

# Generator Shutdown & Tripping

## Operation

This function controls the following:

- shutdown of the driving machine
- tripping of the breaking device
- interruption of the generator excitation supply in case of:
    - detection of an internal generator fault
    - receipt of a genset shutdown command on a logic input or via the communication link.



Generator shutdown and tripping involve:
① tripping of the circuit breaker connecting the machine to the network
② tripping of the excitation circuit breaker
③ shutdown of the prime mover.

The combination of these three commands determines four types of shutdown and tripping commands:

- total shutdown (simultaneous tripping)
- generator tripping
- generator separation
- sequential tripping.

## Total Shutdown

This type of control function gives the following commands simultaneously:

- a trip command to the generator circuit breaker
- a trip command to the excitation circuit breaker
- a shutdown command to the prime mover.

This mode is reserved for internal faults in generators and transformers of generator-transformer units.

## Generator Tripping

This type of control function gives the following commands:

- a trip command to the generator circuit breaker
- a trip command to the excitation circuit breaker.

The prime mover is not shut down.

This mode is reserved for power system faults and allows the generator to be quickly reconnected after the fault is cleared.

## Generator Separation

This type of control function gives a trip command to the generator utility tie circuit breaker. The machine remains excited and the prime mover is not shut down.

This mode is used to isolate the machine from a utility power system which no longer meets the utility tie conditions (voltage, frequency, loss of power system source). The generator may continue to supply loads locally.

## Sequential Tripping

This type of control function gives the following commands consecutively:

- a trip command to the generator circuit breaker
- a delayed trip command to the excitation circuit breaker
- a delayed shutdown command to the prime mover.

This mode is reserved for steam turbine generators and other such machines that may be adversely affected by overspeed during shutdown.

Sepam™ enables these operating modes by combining:

- switchgear control for tripping of the generator circuit breaker
- de-excitation function for tripping of the excitation circuit breaker
- genset shutdown function to command the shutdown of the prime mover.

Function output delays are used for sequential tripping.

## Typical Parameter Setting for Industrial Network Generators

| Protection Functions | Circuit Breaker Tripping | Genset Shutdown | De-Excitation |
|---|---|---|---|
| 12 | ■ | | |
| 21B | ■ | | |
| 24 | ■ | ■ | ■ |
| 27 | ■ | | |
| 32Q | ■ | ■ | ■ |
| 37P | ■ | | |
| 40 | ■ | ■ | ■ |
| 46 | ■ | | |
| 47 | ■ | | |
| 49RMS | ■ | | |
| 50/27 | ■ | | |
| 50/51 | ■ | | |
| 50N/51N<br>50G/51G | ■ | ■ | ■ |
| 50V/51V | ■ | | |
| 59 | ■ | | |
| 59N | ■ | ■ | ■ |
| 64G2/27TN (1) | | | |
| 64REF | ■ | ■ | ■ |
| 67 | ■ | ■ | ■ |
| 67N/NC | ■ | ■ | ■ |
| 78PS | ■ | | |
| 81H | ■ | | |
| 81L | ■ | | |
| 81R | ■ | | |
| 87M | ■ | ■ | ■ |
| 87T | ■ | ■ | ■ |

***(1)** Generally initiates an alarm, but may otherwise initiate circuit breaker tripping, genset shutdown and de-excitation.*

# Generator Shutdown & Tripping
## Genset Shutdown

### Operation

This function is available in generator applications. It is used to shut down the genset in one of two ways:

- mechanical shutdown by shutting down the prime mover
- electrical shutdown by tripping the generator.

Genset shutdown may be initiated in the following ways:

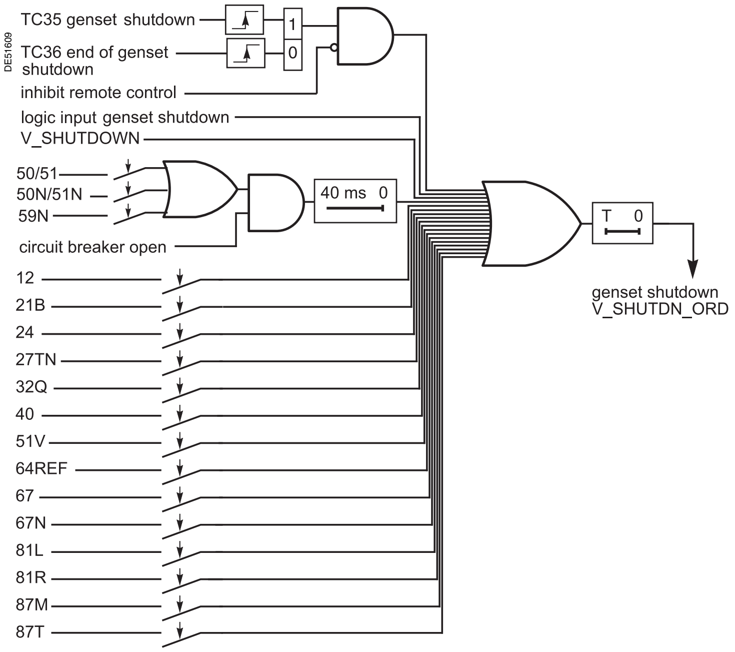
- by a external shutdown command
  - remote control command if enabled
  - logic input if set up
- by logic equation or by Logipam to take into account all specific generator installation characteristics
- by delayed protection functions.

The protection functions concerned are those that detect internal faults in generators or transformers of generator-transformer units. They are divided into 2 groups: protection functions that contribute to shutdown regardless of the circuit breaker position and those whose contribution is dependent on the circuit breaker position:

- protection functions unrelated to circuit breaker position 12, 21B, 24, 27TN, 32Q, 40, 51V, 64REF, 67, 67N, 81L, 87M, 87T
- protection functions dependent on circuit breaker position 50/51, 50N/51N, 59N. The delayed, unlatched outputs of these protection units activate shutdown, only if the circuit breaker is open.

Participation in the function is an individual setting, located in the protection setting tabs of the SFT2841 software for each protection unit that can take part in genset shutdown. At the same time, the function gives a tripping command via switchgear control to disconnect the generator from the power network. It must be associated with a logic output in the matrix to initiate genset shutdown.

### Block Diagram


DE51609
TC35 genset shutdown
TC36 end of genset shutdown
1
0
inhibit remote control
logic input genset shutdown
V_SHUTDOWN
50/51
50N/51N
59N
40 ms 0
circuit breaker open
12
21B
24
27TN
32Q
40
51V
64REF
67
67N
81L
81R
87M
87T
T 0
genset shutdown
V_SHUTDN_ORD

### Characteristics

| **Settings** | |
|---|---|
| **Activity** | |
| Setting range | On / Off |
| **Selection of Protection Functions Activating Genset Shutdown** | |
| Setting range per protection unit | Enabled / disabled |
| **Genset Shutdown Time Delay** | |
| Setting range | 0 to 300 s |
| Accuracy [1] | ±2% or from -10 ms to +25 ms |
| Resolution | 10 ms or 1 digit |

| **Inputs** | | | |
|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** |
| Genset shutdown | V_SHUTDOWN | ■ | ■ |

| **Outputs** | | | | |
|---|---|---|---|---|
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Genset shutdown | V_SHUTDN_ORD | | ■ | ■ |
| Genset shutdown on | V_SHUTDN_ON | | ■ | |

*(1) Under reference conditions (IEC 60255-6).*

## Operation

This function, available in generator applications, is used to quickly cut off the power supply to an internal fault when the generator is disconnected from the network:

- de-excitation of the generator
- electrical shutdown by tripping.

De-excitation may be initiated in the following ways:

- by a command
  - remote control command if enabled
  - logic input if set up
- by logic equation or by Logipam to take into account all specific generator installation characteristics
- by delayed protection functions.

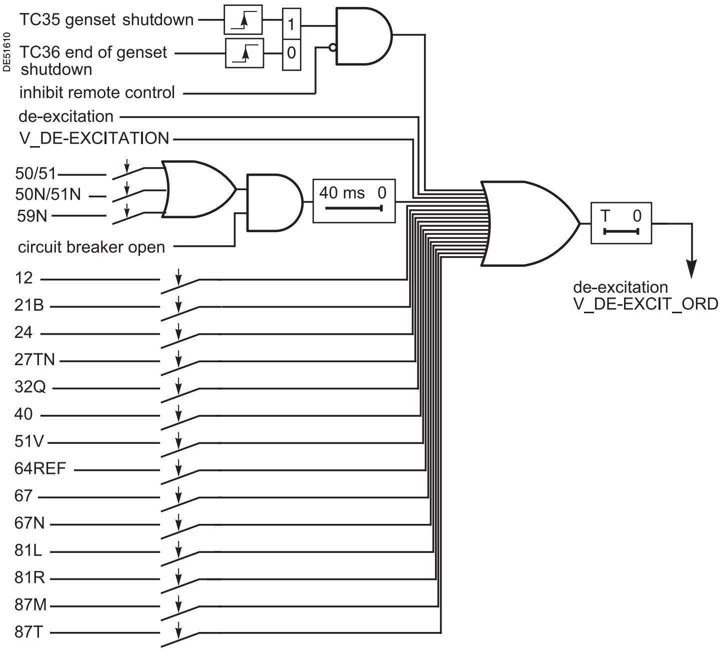
The protection functions concerned are those that detect internal faults in generators or transformers of generator-transformer units. They are divided into 2 groups: protection functions that contribute to de-excitation regardless of the circuit breaker position and those whose contribution is dependent on the circuit breaker position:

- protection functions unrelated to circuit breaker position 12, 21B, 24, 27TN, 32Q, 40, 51V, 59, 64REF, 67, 67N.81L, 87M, 87T
- protection functions dependent on circuit breaker position 50/51, 50N/51N, 59N. The delayed, unlatched outputs of these protection units trigger de-excitation only if the circuit breaker is open.

Participation in the function is to be set individually in the protection function setting tabs of the SFT2841 software for each protection unit that can take part in de-excitation.

At the same time, the function gives a tripping command via switchgear control to disconnect the generator from the power network. It must be associated with a logic output in the control matrix to initiate the de-excitation command.

## Block Diagram



## Characteristics

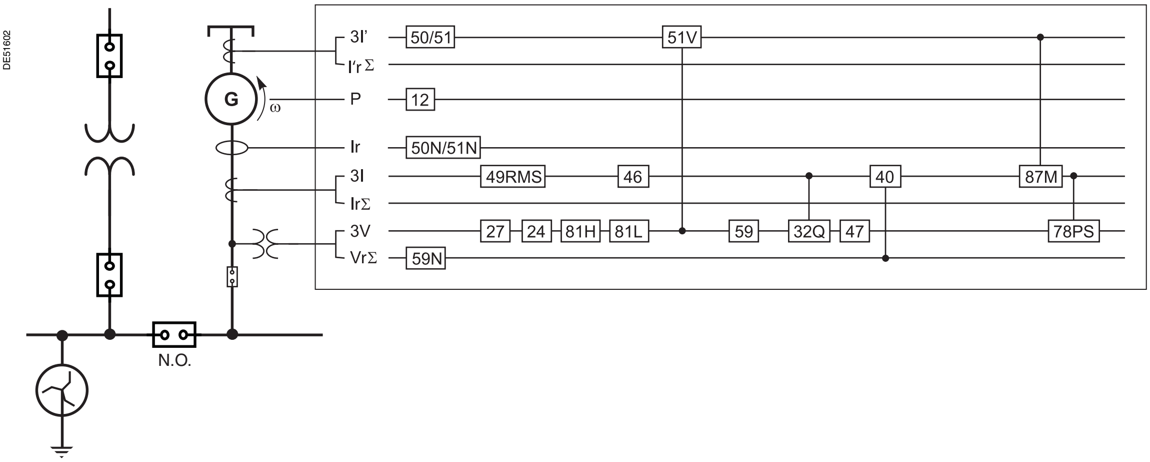
| **Settings** | | | | |
|---|---|---|---|---|
| **Activity** | | | | |
| Setting range | On / Off | | | |
| **Selection of Protection Functions Activating De-Excitation** | | | | |
| Setting range per protection unit | Enabled / disabled | | | |
| **De-Excitation Time Delay** | | | | |
| Setting range | 0 to 300 s | | | |
| Accuracy [(1)] | ±2% or from -10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| De-excitation | V_DE-EXCITATION | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| De-excitation | V_DE-EXCIT_ORD | | ■ | ■ |
| De-excitation on | V_DE-EXCIT_ON | | ■ | |

*(1) Under reference conditions (IEC 60255-6).*

# Generator Shutdown & Tripping
Example

## Installation Description

The electrical installation consists of a bus that connects to::
- a main supplied by a 10 MVA transformer
- a 3.15 MVA power generator



In normal operation, the generator and transformer are connected to the bus. The generator provides backup power to the installation in the absence of the transformer power supply. The installation is grounded by a neutral inductance. When the generator is not connected to the network, its neutral is isolated. When faults occur, the generator is over-excited for 3 - 10 seconds. Its fault current is equal to 3 times its rated current. After the 3 - 10 seconds have elapsed, the fault current drops to 0.5 times the rated current.

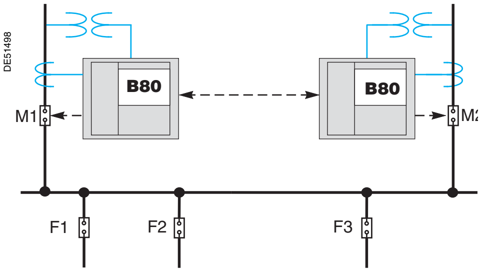
The generator is protected:
- against network electrical short-circuits by a phase overcurrent protection function 50/51 and a backup protection function 50V/51V
- against internal faults in generators by a generator differential protection function 87M.
- against ground faults by a ground fault protection function 50N/51N when the generator is connected to the bus and by a neutral voltage displacement protection function when the generator is not connected
- against overloads by a thermal overload protection function 49RMS
- against unbalance by a negative sequence / unbalance protection function 46
- against frequency variations by underfrequency and overfrequency protection functions 81L and 81H
- against voltage variations by undervoltage and overvoltage protection functions 27 and 59
- against field loss by a protection function 40
- against faults due to the prime mover by a reverse active power protection function 32P
- against loss of synchronization of the main network by a protection function 78PS.

## Setting Genset Shutdown and De-Excitation

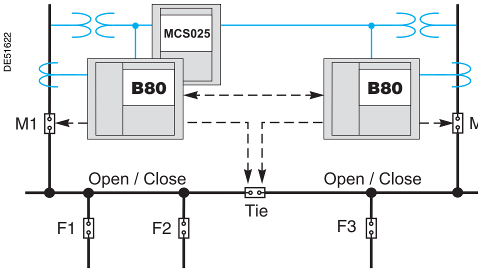
The participation of these protection functions in circuit breaker tripping, genset shutdown and de-excitation depends on the type of faults detected:
- circuit breaker tripping against network faults:
  - ☐ 50/51, 50V/51V, 50N/51N, 49RMS, 46, 81L, 81H, 27, 59, 78PS
- genset shutdown for prime mover faults and internal faults:
  - ☐ 50/51, 87M, 59N, 40
- de-excitation for internal faults:
  - ☐ 50/51, 87M, 59N, 40.

Shutdown is total and not sequential. The genset shutdown and de-excitation time delays are zero.

# Automatic Transfer



*Automatic "transfer "MAIN-MAIN"*



*Automatic transfer "MAIN-TIE-MAIN" with sync-check managed by Sepam™ Series 80*

## Description

The automatic transfer function is used to transfer bus supply from one source to another.
The function reduces bus supply interruptions, thereby increasing the service continuity of the network supplied by the bus.

Automatic transfer performs:

- automatic transfer with interruption if there is a loss of voltage or a fault upstream
- manual transfer and return to normal operation without interruption, with or without sync-check
- control of the tie circuit breaker (optional)
- selection of the normal operating mode
- the necessary logic to ensure that at the end of the sequence, only one circuit breaker out of 2 or 2 out of 3 are closed.

## Automatic "Main-Main" or "Main-Tie-Main" Transfer

Operating and implementing the automatic transfer function depends on the type of substation:

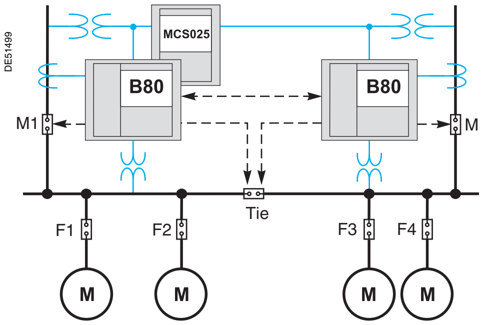
- "Main-main" transfer is suitable for dual-main substations without a tie
- "Main-tie-main" transfer is suitable for dual-main substations with a tie

These two applications are described separately

The automatic transfer function is symmetrical:

- hardware symmetry: dual-main substations, with two incoming circuit breakers, and each main is protected by a Sepam™ Series 80 unit
- functional symmetry: automatic transfer is distributed between the two Sepam™ Series 80 units protecting the two mains.

Each function is described from the viewpoint of one of the two mains, the other main being referred to as the "opposite side" main.



*Automatic "main-tie-main" transfer with sync-check managed by Sepam™ B80.*

## Equipment Used

**Sepam™ Protection Relay**

Each main is protected by a Sepam™ Series 80 unit.

At least two MES120 modules should be added to each Sepam™.

The sync-check function (ANSI 25) is performed by an optional MCS025 module connected to one of the two Sepam™ units.

For busses with motors, it is necessary to check the remnant voltage on the bus during automatic transfer.

Two solutions are proposed:

- protecting the two mains with Sepam™ B80 to:
  - measure the three phase voltages upstream of the circuit breaker and detect the loss of phase voltage
  - measure one additional phase voltage on the bus and detect the presence of remnant voltage
- protecting the two mains with another type of Sepam™ Series 80 and checking the remaining voltage on the bus with Sepam™ B21.

**Local Control of Automatic Transfer**

Local control of automatic transfer requires the following components:

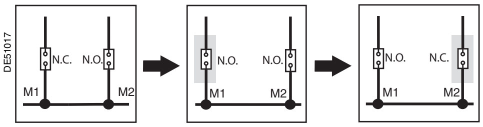
- one "NO circuit breaker" selector (ANSI 10), 2- or 3-position selector which designates the circuit breaker that remains open at the end of voluntary transfer without interruption
- one optional "Manual / Auto" selector (ANSI 43)
  - in Auto mode, automatic transfer is enabled
  - in Manual mode, automatic transfer is disabled
  - when this optional selector is not included, all the automatic transfer functions are enabled.
- as many as three optional "Local / Remote" selectors (one selector for the function or one selector per circuit breaker)
  - in Remote mode, automatic transfer on voltage loss is enabled and the other functions are disabled
  - in Local mode, automatic transfer on voltage loss is disabled and the other functions are enabled
  - when these optional selectors are not included, all the automatic transfer functions are enabled.
- two or three optional pushbuttons with LEDs (one pushbutton per circuit breaker):
  - "Breaker closing" pushbutton
  - "Closing ready" LED.

# Automatic Transfer "Main-Main"
## Operation

### Definition

The automatic "main-main" transfer is suitable for substations supplied by two mains with no tie. This automatic transfer has two functions:

- automatic transfer with bus supply interruption
- voluntary return to normal without bus supply interruption.



Normal Condition

Transfer Condition

Transferred Condition

*Automatic “Main-Main” Transfer*

### Automatic Transfer with Supply Interruption

**Description**

The function transfers bus supply from one source to the other after detecting a voltage loss or fault upstream from the source.

Automatic source transfer takes place in two steps:

- circuit breaker tripping, triggered by detecting the loss of voltage or an external trip command (from upstream protection units): loss of bus supply
- closing the opposite side circuit breaker to resupply the bus (when motors are connected to the bus, it is necessary to check for remaining voltage on the bus using the ANSI 27R Remnant undervoltage function).

**Mandatory Transfer Conditions**

These conditions are always required to enable transfer:

- the incoming circuit breaker is closed
- no phase-to-phase fault detected by the main on the bus or downstream
- no phase-to-ground fault detected by the main on the bus or downstream
- voltage present on the opposite main.

**Optional Transfer Conditions**

These conditions are required when the associated optional functions are enabled:

- the "Auto / Manual" selector is in the Auto position
- the two "Local / Remote" selectors are in the Remote position
- the two incoming circuit breakers are racked in
- no VT fault detected by the VT Supervision function (ANSI 60FL), to avoid transfer on the loss of voltage transformers
- no block of transfer by V_TRANS_STOP by logic equations or by Logipam.

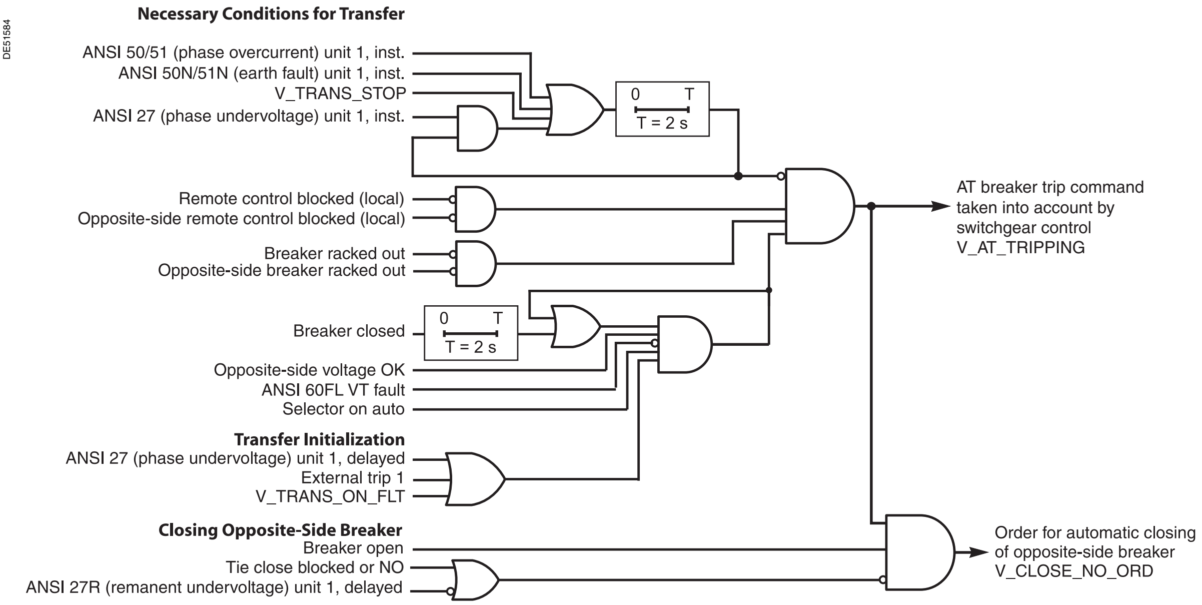
**Initializing Transfer**

Any of the events below can trigger automatic transfer:

- loss of voltage detected on the main by the Phase undervoltage function (ANSI 27)
- detection of a fault by the protection units upstream of the main, with intertripping command on the "External tripping 1" logic input
- V_TRANS_ON_FLT, initialization of transfer by logic equations or by Logipam.

# **Automatic Transfer "Main-Main"** Operation

**Block Diagram**


DE51584
Necessary Conditions for Transfer
ANSI 50/51 (phase overcurrent) unit 1, inst.
ANSI 50N/51N (earth fault) unit 1, inst.
V_TRANS_STOP
ANSI 27 (phase undervoltage) unit 1, inst.
0 T
T = 2 s
Remote control blocked (local)
Opposite-side remote control blocked (local)
Breaker racked out
Opposite-side breaker racked out
Breaker closed
0 T
T = 2 s
Opposite-side voltage OK
ANSI 60FL VT fault
Selector on auto
Transfer Initialization
ANSI 27 (phase undervoltage) unit 1, delayed
External trip 1
V_TRANS_ON_FLT
Closing Opposite-Side Breaker
Breaker open
Tie close blocked or NO
ANSI 27R (remanent undervoltage) unit 1, delayed
AT breaker trip command
taken into account by
switchgear control
V_AT_TRIPPING
Order for automatic closing
of opposite-side breaker
V_CLOSE_NO_ORD

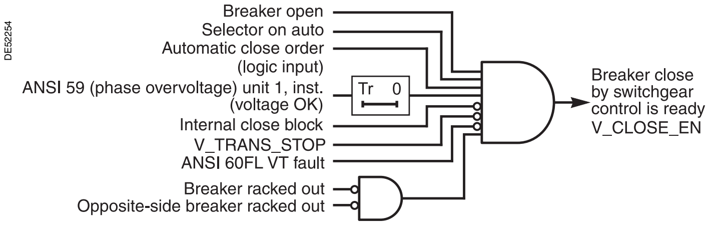
**Closing the Opposite Side Circuit Breaker**

The following conditions are required to command the closing of the opposite side circuit breaker:

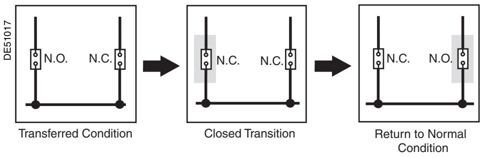
- the circuit breaker is open
- no opposite side circuit breaker block close conditions
- no remnant voltage on the bus (checking necessary when motors are connected to the bus)

The opposite side circuit breaker closing command is transmitted by a Sepam™ logic output to a logic input of the opposite side Sepam™.
It is taken into account by the Switchgear control function of the opposite side Sepam™.

**Block Diagram (Opposite Side Sepam™)**


DE52254
Breaker open
Selector on auto
Automatic close order
(logic input)
ANSI 59 (phase overvoltage) unit 1, inst.
(voltage OK)
Tr 0
Internal close block
V_TRANS_STOP
ANSI 60FL VT fault
Breaker racked out
Opposite-side breaker racked out
Breaker close
by switchgear
control is ready
V_CLOSE_EN

# Automatic Transfer "Main-Main"
Operation


DE51017
N.O.
N.C.
N.C.
N.C.
N.C.
N.O.
Transferred Condition
Closed Transition
Return to Normal Condition

## Voluntary Return to Normal Without Interruption

### Description

The voluntary return to normal without interruption involves two separate control functions:

- closing of the open incoming circuit breaker, with or without sync-check: the two incoming circuit breakers are closed
- then opening of the normally open circuit breaker, designated by the "NO circuit breaker" selector.

These two functions may also be used to transfer the bus supply source without any interruption.

### Mandatory Transfer Conditions

These conditions are required to enable transfer:

- the incoming circuit breaker is open
- the voltage is OK upstream of the incoming circuit breaker.

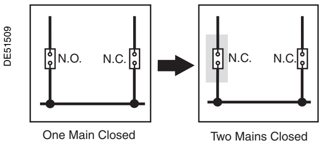
### Optional Transfer Conditions

These conditions are required when the associated optional functions are enabled:

- the "Auto / Manual" selector is in the Manual position
- the 2 "Local / Remote" selectors are in the Local position
- the 2 main circuit breakers are racked in
- no VT fault detected by the VT Supervision function (ANSI 60FL), to avoid transfer on the loss of voltage transformers
- no blocking of transfer by V_TRANS_STOP by logic equations or by Logipam.

### Initializating the Return to Normal

- voluntary incoming circuit breaker close command.


DE51509
N.O.
N.C.
N.C.
N.C.
One Main Closed
Two Mains Closed

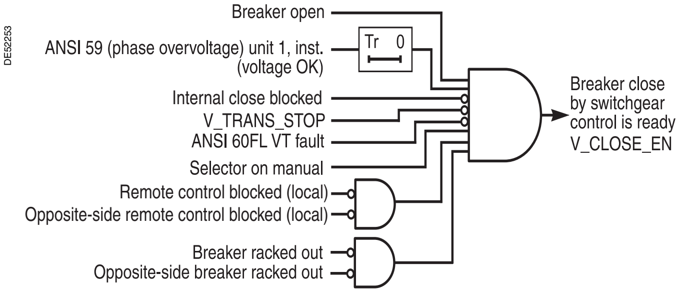
## Closing an Open Circuit Breaker

### Description

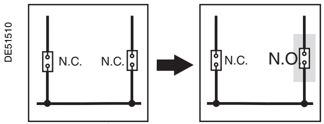
Circuit breaker closing is ensured by the Switchgear control function, with or without sync-check.

The AT function checks that all the required conditions are met and indicates to the user that the return to normal is possible.

### Block Diagram


DE52253
Breaker open
ANSI 59 (phase overvoltage) unit 1, inst. (voltage OK)
Tr 0
Internal close blocked
V_TRANS_STOP
ANSI 60FL VT fault
Selector on manual
Remote control blocked (local)
Opposite-side remote control blocked (local)
Breaker racked out
Opposite-side breaker racked out
Breaker close by switchgear control is ready
V_CLOSE_EN

# **Automatic Transfer "Main-Main"** Operation


DE51510
N.C.
N.C.
N.C.
N.O.

Two Mains Closed

Return to Normal
One Main Closed

## Opening a Normally Open Circuit Breaker

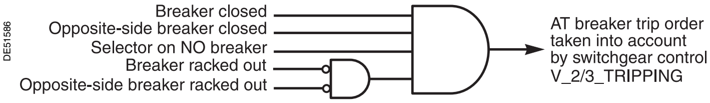
**Description**

This function controls the opening of circuit breakers that are designated "normally open" by the position of the "NO circuit breaker" selector when the two main circuit breakers are closed.

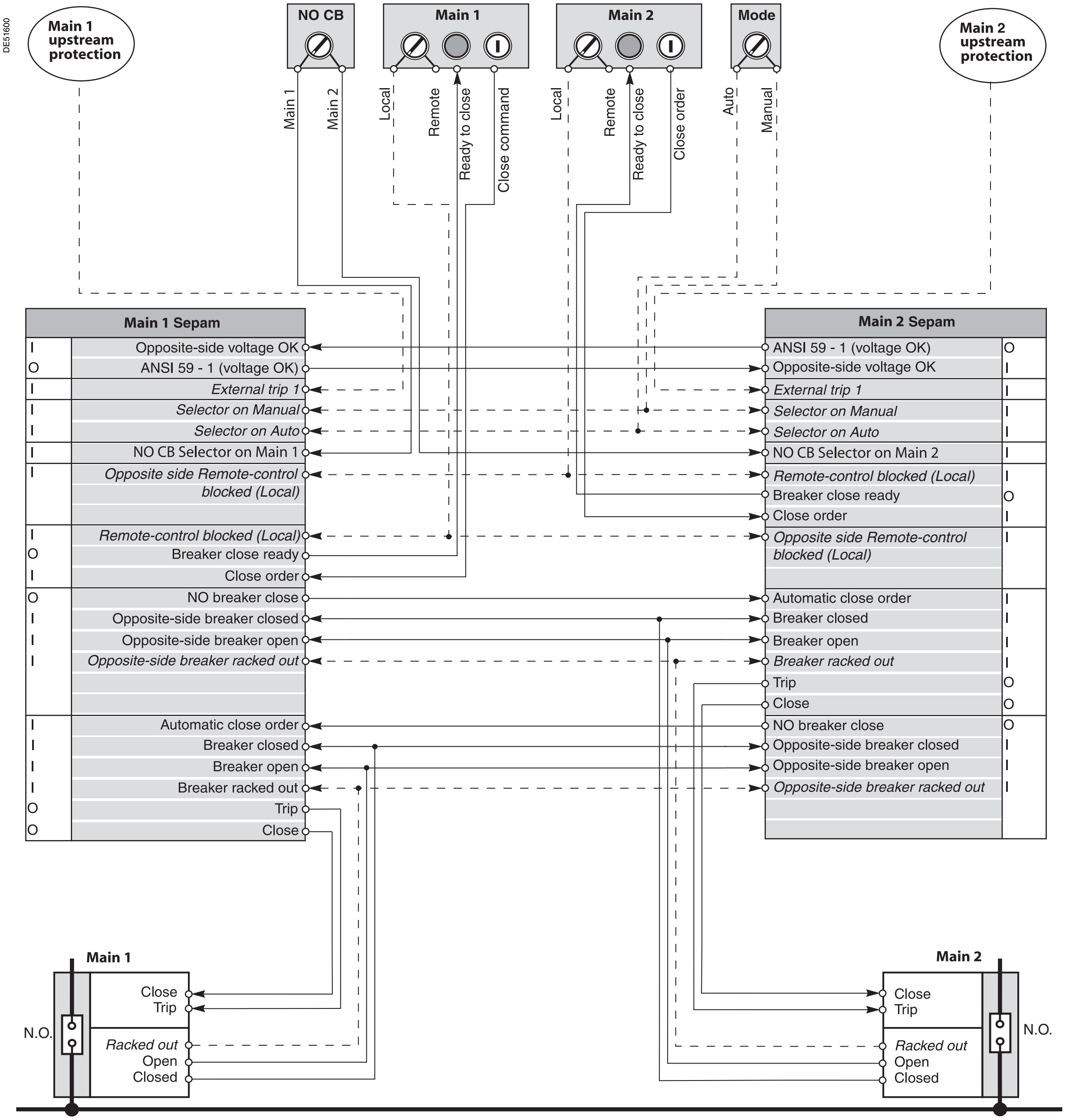
For those automatic control sequences that put the two sources in parallel, it guarantees that only one circuit breaker of the two is closed at the end of the transfer.

The open command is taken into account by the Switchgear control function.

**Block Diagram**


DE51586
Breaker closed
Opposite-side breaker closed
Selector on NO breaker
Breaker racked out
Opposite-side breaker racked out
AT breaker trip order
taken into account
by switchgear control
V_2/3_TRIPPING

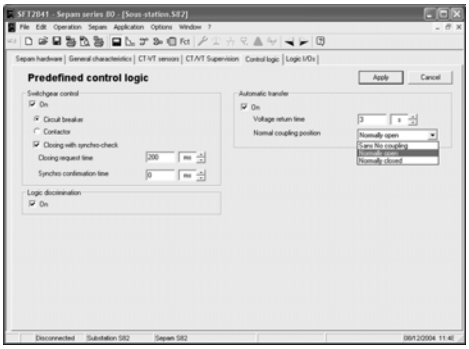
## Connection


DE51600
Main 1 upstream protection
NO CB
Main 1
Main 2
Mode
Main 2 upstream protection
Main 1
Main 2
Local
Remote
Ready to close
Close command
Local
Remote
Ready to close
Close order
Auto
Manual
Main 1 Sepam
I Opposite-side voltage OK
O ANSI 59 - 1 (voltage OK)
I External trip 1
I Selector on Manual
I Selector on Auto
I NO CB Selector on Main 1
I Opposite side Remote-control blocked (Local)
I Remote-control blocked (Local)
O Breaker close ready
I Close order
O NO breaker close
I Opposite-side breaker closed
I Opposite-side breaker open
I Opposite-side breaker racked out
I Automatic close order
I Breaker closed
I Breaker open
I Breaker racked out
O Trip
O Close
Main 2 Sepam
ANSI 59 - 1 (voltage OK) O
Opposite-side voltage OK I
External trip 1 I
Selector on Manual I
Selector on Auto I
NO CB Selector on Main 2 I
Remote-control blocked (Local) I
Breaker close ready O
Close order I
Opposite side Remote-control blocked (Local) I
Automatic close order I
Breaker closed I
Breaker open I
Breaker racked out I
Trip O
Close O
NO breaker close O
Opposite-side breaker closed I
Opposite-side breaker open I
Opposite-side breaker racked out I
Main 1
N.O.
Close
Trip
Racked out
Open
Closed
Main 2
N.O.
Close
Trip
Racked out
Open
Closed

– – – – – – – : *optional wiring.*

# Automatic Transfer "Main-Main"
## Implementation

PE50458


SFT2841 - Sepam series 80 - [Sous-station.S82]
File Edit Operation Sepam Application Options Window ?
Sepam hardware | General characteristics | CT-VT sensors | CT-VT Supervision | Control logic | Logic I/Os
Apply
Cancel
Disconnected
Substation S82
Sepam S82
08/12/2004 11:48

Predefined control logic

Switchgear control
☑ On
● Circuit breaker
○ Contactor
☑ Closing with synchro-check
Closing request time 200 ms
Synchro confirmation time 0 ms

Logic discrimination
☑ On

Automatic transfer
☑ On
Voltage return time 3 s
Normal coupling position Normally open (Sans No coupling / Normally open / Normally closed)

*SFT2841: parameter setting of predefined control logic*

### Parameter Setting: Predefined Control Functions

The Automatic transfer function is set up with the Switchgear control function in the "Control logic" tab of the SFT2841 software.

**Switchgear Control Function**

- activating the Switchgear control function
- activating the Sync-check function if necessary

**Automatic Transfer Function**

- activating the Automatic transfer function and adjustment of associated parameters:
  - voltage return time Tr (typically 3 seconds)
  - normal breaker position: tie open

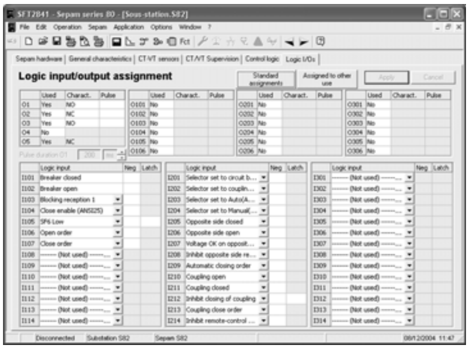
**VT Supervision Function**

Activate the VT supervision (ANSI 60FL, if necessary.

### Protection Function Setting

| Protection Functions | Use | Setting Information |
|---|---|---|
| Phase undervoltage (ANSI 27)<br>Unit 1 | Initialization of automatic transfer on detection of voltage loss. | Voltage set point: 60% $V_{LL}$Np<br>Delay: 300 msec |
| Phase overcurrent (ANSI 50/51)<br>Unit 1, instantaneous output | Detection of downstream phase fault, to block automatic transfer. | To be set according to coordination study (the most sensitive set point). |
| Ground fault (ANSI 50N/51N)<br>Unit 1, instantaneous output | Detection of downstream ground fault, to block automatic transfer. | To be set according to coordination study (the most sensitive set point). |
| Phase overvoltage (ANSI 59)<br>Unit 1 | Detection of phase voltage upstream of the circuit breaker.<br>To be assigned to a Sepam™ logic output in the control matrix. | Voltage set point: 90% $V_{LL}$Np<br>Delay: 3 sec |
| **Optional Protection Functions** | **Use** | **Setting information** |
| Remnant undervoltage (ANSI 27R)<br>Unit 1 | Detection of no remnant voltage on the bus to which the motors are connected. | Voltage set point: 30% $V_{LL}$Np<br>Delay: 100 msec |

# Automatic Transfer "Main-Main"
## Implementation



Logic input/output assignment

| | Used | Charact. | Pulse |
|---|---|---|---|
| O1 | Yes | NO | |
| O2 | Yes | NC | |
| O3 | Yes | NO | |
| O4 | No | | |
| O5 | Yes | NC | |

| | Used | Charact. | Pulse |
|---|---|---|---|
| O101 | No | | |
| O102 | No | | |
| O103 | No | | |
| O104 | No | | |
| O105 | No | | |
| O106 | No | | |

| | Used | Charact. | Pulse |
|---|---|---|---|
| O201 | No | | |
| O202 | No | | |
| O203 | No | | |
| O204 | No | | |
| O205 | No | | |
| O206 | No | | |

| | Used | Charact. | Pulse |
|---|---|---|---|
| O301 | No | | |
| O302 | No | | |
| O303 | No | | |
| O304 | No | | |
| O305 | No | | |
| O306 | No | | |

| | Logic input | Neg | Latch |
|---|---|---|---|
| I101 | Breaker closed | | |
| I102 | Breaker open | | |
| I103 | Blocking reception 1 | | |
| I104 | Close enable (ANSI25) | | |
| I105 | SF6 Low | | |
| I106 | Open order | | |
| I107 | Close order | | |
| I108 | ------- (Not used) -------... | | |
| I109 | ------- (Not used) -------... | | |
| I110 | ------- (Not used) -------... | | |
| I111 | ------- (Not used) -------... | | |
| I112 | ------- (Not used) -------... | | |
| I113 | ------- (Not used) -------... | | |
| I114 | ------- (Not used) -------... | | |

| | Logic input | Neg | Latch |
|---|---|---|---|
| I201 | Selector set to circuit b... | | |
| I202 | Selector set to couplin... | | |
| I203 | Selector set to Auto(A... | | |
| I204 | Selector set to Manual(... | | |
| I205 | Opposite side closed | | |
| I206 | Opposite side open | | |
| I207 | Voltage OK on opposit... | | |
| I208 | Inhibit opposite side re... | | |
| I209 | Automatic closing order | | |
| I210 | Coupling open | | |
| I211 | Coupling closed | | |
| I212 | Inhibit closing of coupling | | |
| I213 | Coupling close order | | |
| I214 | Inhibit remote-control ... | | |

| | Logic input | Neg | Latch |
|---|---|---|---|
| I301 | ------- (Not used) -------... | | |
| I302 | ------- (Not used) -------... | | |
| I303 | ------- (Not used) -------... | | |
| I304 | ------- (Not used) -------... | | |
| I305 | ------- (Not used) -------... | | |
| I306 | ------- (Not used) -------... | | |
| I307 | ------- (Not used) -------... | | |
| I308 | ------- (Not used) -------... | | |
| I309 | ------- (Not used) -------... | | |
| I310 | ------- (Not used) -------... | | |
| I311 | ------- (Not used) -------... | | |
| I312 | ------- (Not used) -------... | | |
| I313 | ------- (Not used) -------... | | |
| I314 | ------- (Not used) -------... | | |

Disconnected    Substation S82    Sepam S82    08/12/2004 11:47

*SFT2841: standard assignment of the inputs required for the AT function*

### Logic Input Assignment

The logic inputs required for the AT function are assigned in the SFT2841 "Logic I/Os" screen.

The "Standard assignments" button suggests an assignment of the main inputs required for the AT function. The other inputs are assigned manually.

### Logic Output Assignment in the Control Matrix

The assignment of the logic outputs required for the AT function takes place in two steps:

1. declaring the required logic outputs "Used", indicating the control mode of each output, in the SFT2841 "Logic I/Os" screen
2. assigning each predefined output associated with the AT function to a Sepam™ logic output in the SFT2841 "Control matrix" screen.

The predefined outputs associated with the AT function are as follows:

| **"Protection" Button** | **Description** | **Use** |
|---|---|---|
| 59 - 1 | Delayed output of the Phase overvoltage function (ANSI 59) Unit 1 | Indication for the opposite side Sepam™: the voltage is OK upstream of the incoming circuit breaker. |
| **"Logic" Button** | **Description** | **Use** |
| NO circuit breaker closing | Predefined output V_CLOSE_NO_ORD of the AT function | Automatic closing command of opposite side circuit breaker. |
| Breaker closing ready | Predefined output V_CLOSE_EN of the AT function | LED indication:<br>the return to normal conditions are met (neglecting the sync-check) |

# Automatic Transfer "Main-Main"
## Characteristics

| **Setting** | | | | |
|---|---|---|---|---|
| **Activity** | | | | |
| Setting range | On / Off | | | |
| **Voltage Return Time** | | | | |
| Setting range | 0 to 300 s | | | |
| Accuracy (1) | ±2% or from –10 msec to +25 msec | | | |
| Resolution | 10 msec or 1 digit | | | |
| **Normal Tie Breaker Position** | | | | |
| Setting range | No tie / Normally open / Normally closed | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Transfer command on fault | V_TRANS_ON_FLT | ■ | ■ | |
| Transfer off command | V_TRANS_STOP | ■ | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Automatic transfer on | V_TRANSF_ON | | ■ | |
| Tripping by 2/3 or 1/2 logic | V_2/3_TRIPPING | | ■ | ■ |
| Tripping by automatic transfer | V_AT_TRIPPING | | ■ | ■ |
| NO circuit breaker closing | V_CLOSE_NO_ORD | | ■ | ■ |
| Breaker closing ready | V_CLOSE_EN | | ■ | ■ |

***(1)** Under reference conditions (IEC 60255-6).*

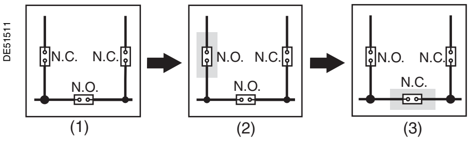
Schneider Electric

# Automatic Transfer "Main-Tie-Main"
Operation

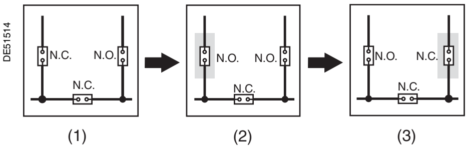
## Definition

The "Main-Tie-Main" (M-T-M) transfer is automatic and is suitable for substations with bus supplied by two mains and with a tie (M-T-M). Automatic transfer is made up of two functions:

1. automatic transfer with bus supply interruption
2. voluntary return to normal without bus supply interruption.



*Automatic transfer with normally open tie*
*(1) Normal condition*
*(2) Transfer condition*
*(3) Transferred condition*



*Automatic transfer with normally closed tie*
*(1) Normal condition*
*(2) Transfer condition*
*(3) Transferred condition*

## Automatic Transfer with Supply Interruption

### Description

This function transfers bus supply from one source to the other after detecting a voltage loss or a fault that is upstream of the source.

Automatic source transfer takes place in two steps:

1. tripping the circuit breaker triggered by the detection of the loss of voltage or an external trip command (trip command from upstream protection unit): loss of bus supply
2. closing the normally open circuit breaker to resupply the bus. According to the parameter setting, the normally open circuit breaker may be one of the following:
   - the tie circuit breaker, when the tie is normally open
   - the opposite side circuit breaker, when the tie is normally closed.

     When motors are connected to the bus, it is necessary to check for remnant voltage on the bus using the remnant undervoltage function (ANSI 27R).

### Mandatory Transfer Conditions

These conditions are always required to enable transfer:

- the incoming circuit breaker is closed
- according to the tie setup:
  - the opposite side circuit breaker is closed and the tie circuit breaker is open, when the tie is normally open
  - or the opposite side circuit breaker is open and the tie circuit breaker is closed, when tie breaker is normally closed
- no phase-to-phase fault detected by the main on the bus or downstream
- no phase-to-ground fault detected by the main on the bus or downstream
- voltage OK on the opposite main.

### Optional Transfer Conditions

These conditions are required when the associated optional functions are enabled:

- the "Auto / Manual" selector is in the Auto position
- the three "Local / Remote" selectors are in the Remote position
- the three circuit breakers are racked in
- no VT fault detected by the VT Supervision function (ANSI 60FL), to avoid transfer on the loss of voltage transformers
- no blocking transfer by V_TRANS_STOP by logic equations or by Logipam.

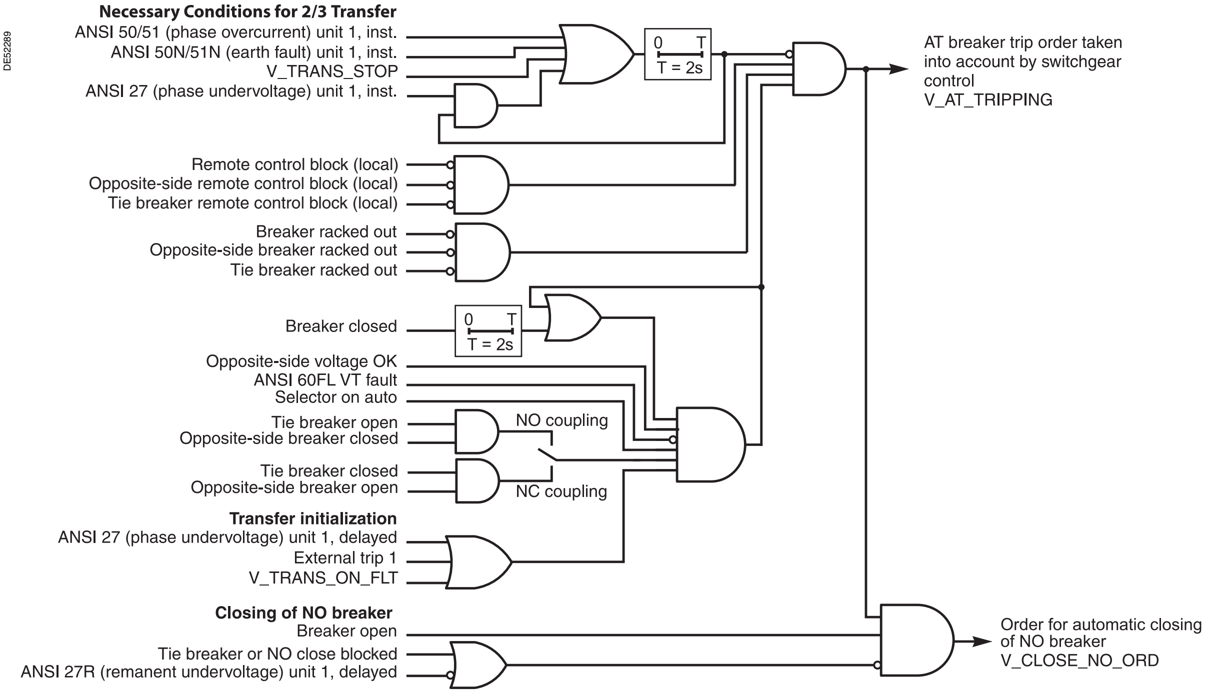
### Initializing Transfer

Any of the following events can trigger automatic transfer:

- loss of voltage detected on the main by the Phase undervoltage function (ANSI 27)
- or the detection of a fault by the protection units upstream of the main, with a tripping command on the "External tripping 1" logic input
- or V_TRANS_ON_FLT, initialization of transfer by logic equations or by Logipam.

# Automatic Transfer "Main-Tie-Main"
## Operation

**Block Diagram**


DE52289
Necessary Conditions for 2/3 Transfer
ANSI 50/51 (phase overcurrent) unit 1, inst.
ANSI 50N/51N (earth fault) unit 1, inst.
V_TRANS_STOP
ANSI 27 (phase undervoltage) unit 1, inst.
0 T
T = 2s
AT breaker trip order taken into account by switchgear control
V_AT_TRIPPING
Remote control block (local)
Opposite-side remote control block (local)
Tie breaker remote control block (local)
Breaker racked out
Opposite-side breaker racked out
Tie breaker racked out
Breaker closed
0 T
T = 2s
Opposite-side voltage OK
ANSI 60FL VT fault
Selector on auto
Tie breaker open
Opposite-side breaker closed
NO coupling
Tie breaker closed
Opposite-side breaker open
NC coupling
Transfer initialization
ANSI 27 (phase undervoltage) unit 1, delayed
External trip 1
V_TRANS_ON_FLT
Closing of NO breaker
Breaker open
Tie breaker or NO close blocked
ANSI 27R (remanent undervoltage) unit 1, delayed
Order for automatic closing of NO breaker
V_CLOSE_NO_ORD

**Closing a Normally Open Circuit Breaker**

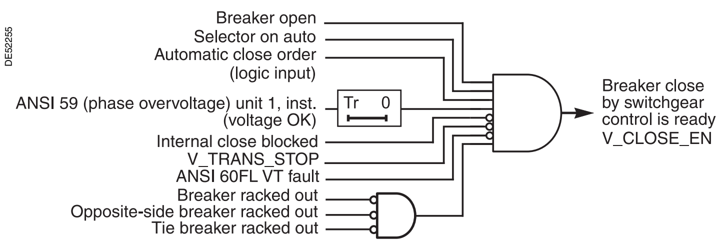
The following conditions must be met to close the normally open circuit breaker:

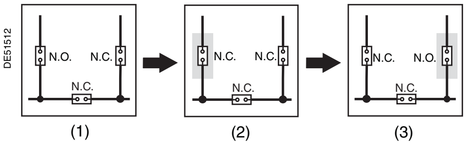
- the incoming circuit breaker is open
- no normally open circuit breaker block close conditions
- no remnant voltage on the bus (checking necessary when motors are connected to the bus)

If the normally open circuit breaker is the opposite side circuit breaker, the NO circuit breaker closing command is transmitted by a Sepam™ logic output to a logic input of the opposite side Sepam™ where it is evaluated by the Switchgear control function (see block diagram below).

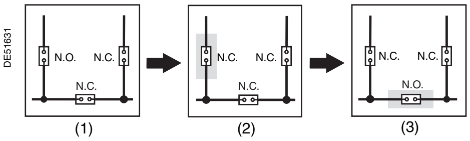
If the normally open circuit breaker is the tie circuit breaker, the NO circuit breaker closing command is transmitted by a Sepam™ logic output to close the circuit breaker directly, without any intermediary.

**Block Diagram (Opposite Side Sepam™)**


DE52255
Breaker open
Selector on auto
Automatic close order (logic input)
ANSI 59 (phase overvoltage) unit 1, inst. (voltage OK)
Tr 0
Internal close blocked
V_TRANS_STOP
ANSI 60FL VT fault
Breaker racked out
Opposite-side breaker racked out
Tie breaker racked out
Breaker close by switchgear control is ready
V_CLOSE_EN


DE51512
N.O.
N.C.
N.C.
N.C.
N.C.
N.C.
N.C.
N.O.
N.C.
(1)
(2)
(3)

*Voluntary return to normal with normally closed tie*
*(1) Transferred condition*
*(2) Closed Transition*
*(3) Return to normal condition*


DE51631
N.O.
N.C.
N.C.
N.C.
N.C.
N.C.
N.C.
N.C.
N.O.
(1)
(2)
(3)

*Voluntary return to normal with normally open tie*
*(1) Transferred condition*
*(2) Closed transition*
*(3) Return to normal condition*

## Voluntary Return to Normal without Interruption

### Description

The voluntary return to normal without interruption involves two separate control functions:

1 closing the open circuit breaker with or without sync-check. The three circuit breakers are closed
2 opening the normally open circuit breaker (designated by the "NO circuit breaker" selector).

These two functions may also be used to transfer the bus supply source without any interruption.

### Mandatory Transfer Conditions

These conditions are required to enable transfer:

- the incoming circuit breaker is open
- the opposite side circuit breaker and the tie circuit breaker are closed
- The voltage is OK upstream of the incoming circuit breaker. This voltage is detected either by function ANSI 59, or by a processing operation in Logipam using V_TRANS_V_EN.

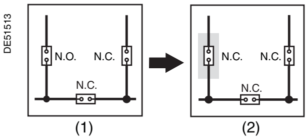
### Optional Transfer Conditions

These conditions are required when the associated optional functions are enabled:

- the "Auto / Manual" selector is in the Manual position
- the three "Local / Remote" selectors are in the Local position
- the three circuit breakers are racked in
- no VT fault detected by the VT Supervision function (ANSI 60FL), to avoid transfer on the loss of voltage transformers
- no blocking of transfer by V_TRANS_STOP by logic equations or by Logipam.

### Initializating the Return to Normal

- voluntary incoming circuit breaker close command.


DE51513
N.O.
N.C.
N.C.
N.C.
N.C.
N.C.
(1)
(2)

*Closing the Open Circuit Breaker*
*(1) One Main open*
*(2) Two Mains closed*

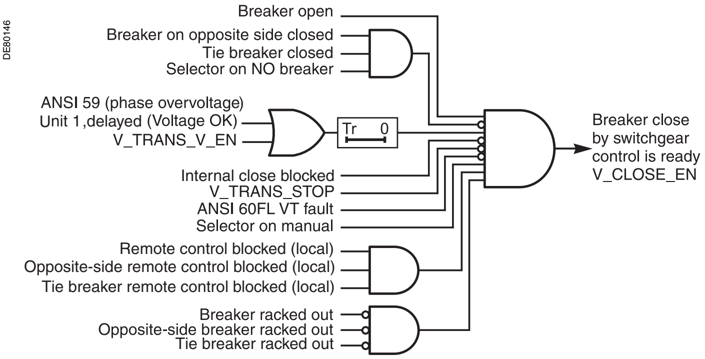
## Closing the Open Circuit Breaker

### Description

Circuit breaker closing is ensured by the Switchgear control function, with or without sync-check.

The AT function checks that all the required conditions are met and indicates to the user that the return to normal is possible.

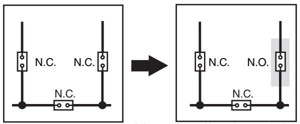
### Block Diagram


DE80146
Breaker open
Breaker on opposite side closed
Tie breaker closed
Selector on NO breaker
ANSI 59 (phase overvoltage)
Unit 1 ,delayed (Voltage OK)
V_TRANS_V_EN
Tr 0
Internal close blocked
V_TRANS_STOP
ANSI 60FL VT fault
Selector on manual
Remote control blocked (local)
Opposite-side remote control blocked (local)
Tie breaker remote control blocked (local)
Breaker racked out
Opposite-side breaker racked out
Tie breaker racked out
Breaker close by switchgear control is ready
V_CLOSE_EN

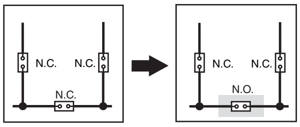
# Automatic Transfer "Main-Tie-Main"

## Operation

DE51529


N.C.
N.C.
N.C.
N.C.
N.O.
N.C.

*Return to normal with normally closed tie*


N.C.
N.C.
N.C.
N.C.
N.C.
N.O.

*Return to normal with normally open tie*

### Opening the Normally Open Circuit Breaker

**Description**

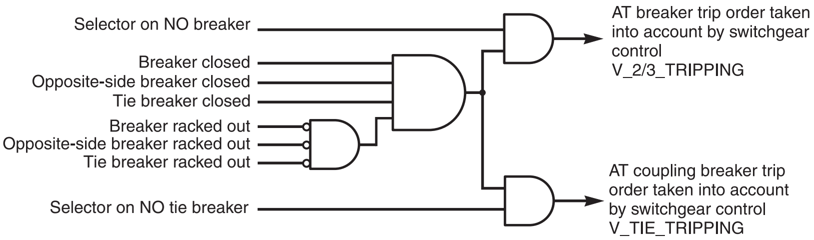
This function controls the opening of the circuit breaker that is designated "normally open" by the position of the "NO circuit breaker" selector, when the three circuit breakers are closed.

For all automatic control sequences that put the two sources in parallel, it guarantees, that only two of the three circuit breakers are closed at the end of the transfer.

The open command is taken into account by the Switchgear control function.

**Block Diagram**

DE51589


Selector on NO breaker
Breaker closed
Opposite-side breaker closed
Tie breaker closed
Breaker racked out
Opposite-side breaker racked out
Tie breaker racked out
Selector on NO tie breaker
AT breaker trip order taken into account by switchgear control V_2/3_TRIPPING
AT coupling breaker trip order taken into account by switchgear control V_TIE_TRIPPING

## Closing Tie

### Description

The voluntary closing of the tie circuit breaker without interruption involves two separate control functions:

1. closing the tie circuit breaker regardless of sync-check. The three circuit breakers are closed.
2. opening the normally open circuit breaker, designated by the "NO circuit breaker" selector.

### Mandatory Transfer Conditions

These conditions are required to enable transfer:

- the opposite side voltage is OK
- the following conditions are not fulfilled simultaneously:
  - ☐ the main circuit breaker is closed
  - ☐ the opposite side circuit breaker is closed
  - ☐ the tie breaker is the normally open circuit breaker (NO tie).

### Optional Transfer Conditions

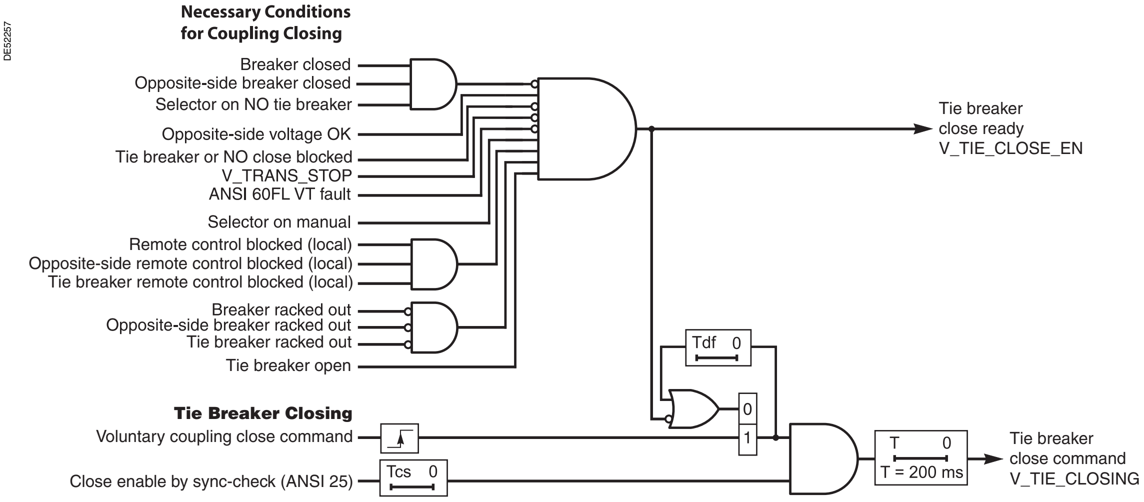
These conditions are required when the associated optional functions are enabled:

- the "Auto / Manual" selector is in the Manual position
- the three "Local / Remote" selectors are in the Local position
- the three circuit breakers are racked in
- no VT fault detected by the VT Supervision function (ANSI 60FL), to avoid transfer on the loss of voltage transformers
- no blocking transfer by V_TRANS_STOP by logic equations or by Logipam.

### Initializing Tie Closing

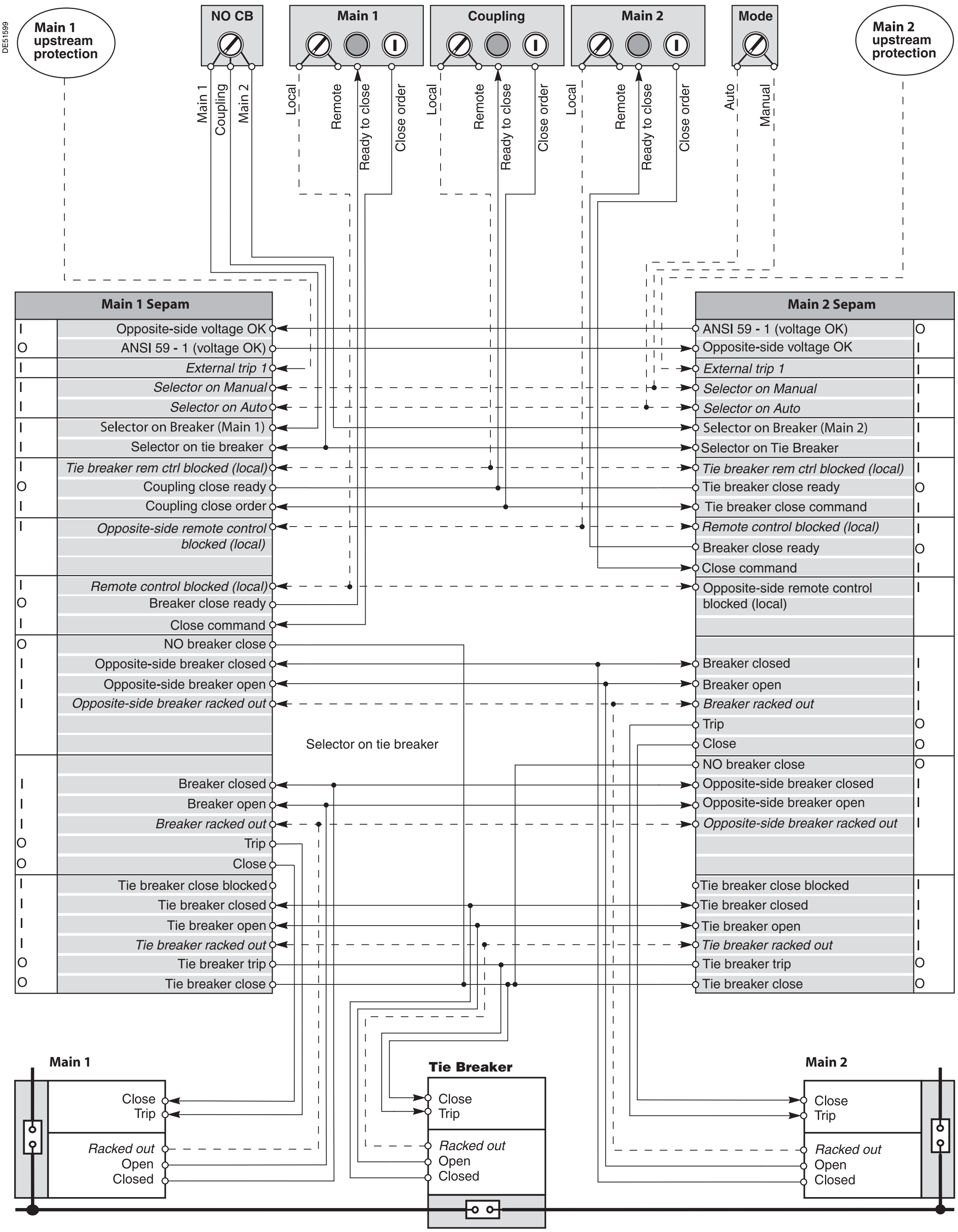
Voluntary tie close command.

### Block Diagram


DE52257
Necessary Conditions for Coupling Closing
Breaker closed
Opposite-side breaker closed
Selector on NO tie breaker
Opposite-side voltage OK
Tie breaker or NO close blocked
V_TRANS_STOP
ANSI 60FL VT fault
Selector on manual
Remote control blocked (local)
Opposite-side remote control blocked (local)
Tie breaker remote control blocked (local)
Breaker racked out
Opposite-side breaker racked out
Tie breaker racked out
Tie breaker open
Tie breaker close ready
V_TIE_CLOSE_EN
Tdf 0
0
1
Tie Breaker Closing
Voluntary coupling close command
Close enable by sync-check (ANSI 25)
Tcs 0
T 0
T = 200 ms
Tie breaker close command
V_TIE_CLOSING

# Automatic Transfer "Main-Tie-Main" Implementation

## Connection for Normally Open Tie


DE51599
Main 1 upstream protection
NO CB
Main 1
Coupling
Main 2
Mode
Main 2 upstream protection
Main 1
Coupling
Main 2
Local
Remote
Ready to close
Close order
Local
Remote
Ready to close
Close order
Local
Remote
Ready to close
Close order
Auto
Manual
Main 1 Sepam
Opposite-side voltage OK
ANSI 59 - 1 (voltage OK)
External trip 1
Selector on Manual
Selector on Auto
Selector on Breaker (Main 1)
Selector on tie breaker
Tie breaker rem ctrl blocked (local)
Coupling close ready
Coupling close order
Opposite-side remote control blocked (local)
Remote control blocked (local)
Breaker close ready
Close command
NO breaker close
Opposite-side breaker closed
Opposite-side breaker open
Opposite-side breaker racked out
Breaker closed
Breaker open
Breaker racked out
Trip
Close
Tie breaker close blocked
Tie breaker closed
Tie breaker open
Tie breaker racked out
Tie breaker trip
Tie breaker close
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Selector on tie breaker
Main 2 Sepam
ANSI 59 - 1 (voltage OK)
Opposite-side voltage OK
External trip 1
Selector on Manual
Selector on Auto
Selector on Breaker (Main 2)
Selector on Tie Breaker
Tie breaker rem ctrl blocked (local)
Tie breaker close ready
Tie breaker close command
Remote control blocked (local)
Breaker close ready
Close command
Opposite-side remote control blocked (local)
Breaker closed
Breaker open
Breaker racked out
Trip
Close
NO breaker close
Opposite-side breaker closed
Opposite-side breaker open
Opposite-side breaker racked out
Tie breaker close blocked
Tie breaker closed
Tie breaker open
Tie breaker racked out
Tie breaker trip
Tie breaker close
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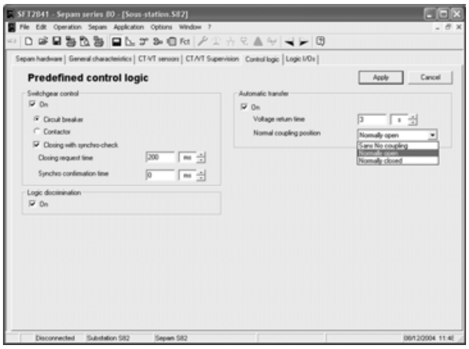
Main 1
Close
Trip
Racked out
Open
Closed
Tie Breaker
Close
Trip
Racked out
Open
Closed
Main 2
Close
Trip
Racked out
Open
Closed

– – – – – – – : *optional wiring*

# Automatic Transfer "Main-Tie-Main"
## Implementation

PE50458


SFT2841 - Sepam series 80 - [Sous-station.S82]
File Edit Operation Sepam Application Options Window ?
Fct
Sepam hardware | General characteristics | CT-VT sensors | CT-VT Supervision | Control logic | Logic I/Os
Apply
Cancel
Disconnected
Substation S82
Sepam S82
08/12/2004 11:48

**Predefined control logic**

Switchgear control
- ☑ On
- ● Circuit breaker
- ○ Contactor
- ☑ Closing with synchro-check
- Closing request time: 200 ms
- Synchro confirmation time: 0 ms

Logic discrimination
- ☑ On

Automatic transfer
- ☑ On
- Voltage return time: 3 s
- Normal coupling position: Normally open (Sans No coupling / Normally open / Normally closed)

*SFT2841: parameter setting of predefined control logic*

## Parameter Setting of Predefined Control Functions

The Automatic transfer function is set up at the same time as the Switchgear control function in the "Control logic" tab of the SFT2841 software.

### Switchgear Control Function

- activation of the Switchgear control function
- activation of the Sync-check function if necessary.

### Automatic Transfer Function

- activation of the Automatic transfer function and adjustment of associated parameters:
  - voltage return time Tr (typically 3 sec)
  - normal tie position: normally open or normally closed, according to the network operating mode.

### VT Supervision Function

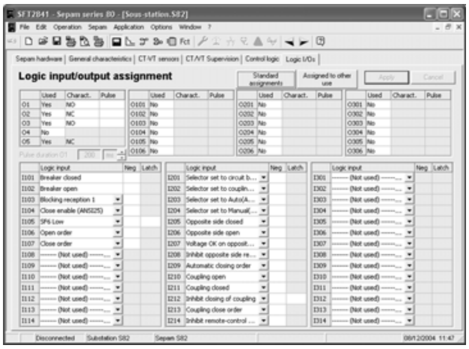
The VT supervision (ANSI 60FL) is to be activated if necessary.

## Protection Function Setting

| Protection Functions | Use | Setting Information |
|---|---|---|
| Phase undervoltage (ANSI 27)<br>Unit 1 | Initialization of automatic transfer on detection of voltage loss. | Voltage set point: 60% $V_{LL}$Np<br>Delay: 300 msec |
| Phase overcurrent<br>(ANSI 50/51)<br>Unit 1, instantaneous output | Detection of downstream phase fault, to block automatic transfer. | To be set according to coordination study (the most sensitive set point). |
| Ground fault (ANSI 50N/51N)<br>Unit 1, instantaneous output | Detection of downstream ground fault, to block automatic transfer. | To be set according to coordination study (the most sensitive set point). |
| Phase overvoltage (ANSI 59)<br>Unit 1 | Detection of phase voltage upstream of the circuit breaker.<br>To be assigned to a Sepam™ logic output in the control matrix. | Voltage set point: 90% $V_{LL}$Np<br>Delay: 3 sec |
| **Optional Protection Functions** | **Use** | **Setting Information** |
| Remnant undervoltage<br>(ANSI 27R)<br>Unit 1 | Detection of no remnant voltage on the bus to which the motors are connected. | Voltage set point: 30% $V_{LL}$Np<br>Delay: 100 msec |

# Automatic Transfer "Main-Tie-Main"

## Implementation



Logic input/output assignment

| | Used | Charact. | Pulse |
|---|---|---|---|
| O1 | Yes | NO | |
| O2 | Yes | NC | |
| O3 | Yes | NO | |
| O4 | No | | |
| O5 | Yes | NC | |

Pulse duration O1 200 ms

| | Used | Charact. | Pulse |
|---|---|---|---|
| O101 | No | | |
| O102 | No | | |
| O103 | No | | |
| O104 | No | | |
| O105 | No | | |
| O106 | No | | |

| | Used | Charact. | Pulse |
|---|---|---|---|
| O201 | No | | |
| O202 | No | | |
| O203 | No | | |
| O204 | No | | |
| O205 | No | | |
| O206 | No | | |

| | Used | Charact. | Pulse |
|---|---|---|---|
| O301 | No | | |
| O302 | No | | |
| O303 | No | | |
| O304 | No | | |
| O305 | No | | |
| O306 | No | | |

| | Logic input | Neg | Latch |
|---|---|---|---|
| I101 | Breaker closed | | |
| I102 | Breaker open | | |
| I103 | Blocking reception 1 | | |
| I104 | Close enable (ANSI25) | | |
| I105 | SF6 Low | | |
| I106 | Open order | | |
| I107 | Close order | | |
| I108 | ------- (Not used) -------... | | |
| I109 | ------- (Not used) -------... | | |
| I110 | ------- (Not used) -------... | | |
| I111 | ------- (Not used) -------... | | |
| I112 | ------- (Not used) -------... | | |
| I113 | ------- (Not used) -------... | | |
| I114 | ------- (Not used) -------... | | |

| | Logic input | Neg | Latch |
|---|---|---|---|
| I201 | Selector set to circuit b... | | |
| I202 | Selector set to couplin... | | |
| I203 | Selector set to Auto(A... | | |
| I204 | Selector set to Manual(... | | |
| I205 | Opposite side closed | | |
| I206 | Opposite side open | | |
| I207 | Voltage OK on opposit... | | |
| I208 | Inhibit opposite side re... | | |
| I209 | Automatic closing order | | |
| I210 | Coupling open | | |
| I211 | Coupling closed | | |
| I212 | Inhibit closing of coupling | | |
| I213 | Coupling close order | | |
| I214 | Inhibit remote-control ... | | |

| | Logic input | Neg | Latch |
|---|---|---|---|
| I301 | ------- (Not used) -------... | | |
| I302 | ------- (Not used) -------... | | |
| I303 | ------- (Not used) -------... | | |
| I304 | ------- (Not used) -------... | | |
| I305 | ------- (Not used) -------... | | |
| I306 | ------- (Not used) -------... | | |
| I307 | ------- (Not used) -------... | | |
| I308 | ------- (Not used) -------... | | |
| I309 | ------- (Not used) -------... | | |
| I310 | ------- (Not used) -------... | | |
| I311 | ------- (Not used) -------... | | |
| I312 | ------- (Not used) -------... | | |
| I313 | ------- (Not used) -------... | | |
| I314 | ------- (Not used) -------... | | |

*SFT2841: standard assignment of the inputs required for the AT function*

### Logic Input Assignment

The logic inputs required for the "AT" function are assigned in the SFT2841 "Logic I/Os" screen.

The "Standard assignments" button suggests an assignment of the main inputs required for the "AT" function. The other inputs are assigned manually.

### Logic Output Assignment in the Control Matrix

The assignment of the logic outputs required for the AT function takes place in two steps:

1. declaring the required logic outputs "Used", indicating the control mode of each output, in the SFT2841 "Logic I/Os" screen
2. assigning each predefined output associated with the AT function to a Sepam™ logic output in the SFT2841 "Control matrix" screen.

The predefined outputs associated with the AT function are as follows:

| "Protection" button | Description | Use |
|---|---|---|
| 59 - 1 | Delayed output of the Phase overvoltage function (ANSI 59) Unit 1 | Indication for the opposite side Sepam™: voltage OK upstream of the incoming circuit breaker. |
| **"Logic" button** | **Description** | **Use** |
| NO circuit breaker closing | Predefined output V_CLOSE_NO_ORD of the AT function | Automatic closing command of normally open circuit breaker. |
| Tie closing | Predefined output V_TIE_CLOSING of the AT function | Tie close command. |
| Tie tripping | Predefined output V_TIE_OPENING of the AT function | Tie open command. |
| Breaker closing ready | Predefined output V_CLOSE_EN of the AT function | LED indication: the return to normal conditions are met. (neglecting the sync-check) |
| Tie closing ready | Predefined output V_TIE_CLOSE_EN of the AT function | LED indication: the tie close conditions are met. (neglecting the sync-check) |

# Automatic Transfer "Main-Tie-Main"
## Characteristics

| **Setting** | | | | |
|---|---|---|---|---|
| **Activity** | | | | |
| Setting range | On / Off | | | |
| **Voltage Return Time** | | | | |
| Setting range | 0 to 300 s | | | |
| Accuracy (1) | ±2% or from –10 ms to +25 ms | | | |
| Resolution | 10 ms or 1 digit | | | |
| **Normal Tie Position** | | | | |
| Setting range | No tie / Normally open / Normally closed | | | |
| **Inputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | |
| Transfer command on fault | V_TRANS_ON_FLT | ■ | ■ | |
| Transfer off command | V_TRANS_STOP | ■ | ■ | |
| Voltage OK upstream of the incoming circuit breaker | V_TRANS _ V_EN | | ■ | |
| **Outputs** | | | | |
| **Designation** | **Syntax** | **Equations** | **Logipam** | **Matrix** |
| Automatic transfer on | V_TRANSF_ON | | ■ | |
| Tripping by 2/3 or 1/2 logic | V_2/3_TRIPPING | | ■ | ■ |
| Tripping by automatic transfer | V_AT_TRIPPING | | ■ | ■ |
| NO circuit breaker closing | V_CLOSE_NO_ORD | | ■ | ■ |
| Breaker closing ready | V_CLOSE_EN | | ■ | ■ |
| Tie tripping | V_TIE_OPENING | | ■ | ■ |
| Tie closing ready | V_TIE_CLOSE_EN | | ■ | ■ |
| Tie closing | V_TIE_CLOSING | | ■ | ■ |
| Tie closing with sync-check failed | V_TIESYNCFAIL | | ■ | ■ |

***(1)** Under reference conditions (IEC 60255-6).*

# Local Indication
## ANSI Code 30

### Operation

Events may be displayed locally on the front panel of Sepam™ by:

- a message on the display
- switching on of one of the 9 yellow LEDs.

### Message Type Indication

**Predefined Messages**

All messages connected to the standard Sepam™ functions are predefined and available in two language versions:

- in English, factory-set messages (not modifiable)
- in the local language, according to the version delivered.

The language version is chosen when Sepam™ parameters are set.

The messages are visible on the Sepam™ display and on the SFT2841 Alarms screen.
The number and type of predefined messages depend on the type of Sepam™. The table below gives the complete list of all predefined messages.

| Functions | | | UK English | US English |
|---|---|---|---|---|
| **Control and Monitoring** | **ANSI Code** | | | |
| External trip (1 to 3) | | | EXT. TRIP (1 to 3) | EXTERNAL TRIP (1 to 3) |
| Buchholz trip | | | BUCHH/GAS TRIP | BUCHH/GAS TRIP |
| Buchholz alarm | | | BUCHHOLZ ALARM | BUCHHOLZ ALARM |
| Thermostat trip | | | THERMOS$^{T}$. TRIP | THERMOS$^{T}$. TRIP |
| Thermostat alarm | | | THERMOS$^{T}$. ALARM | THERMOS$^{T}$. ALARM |
| Pressure trip | | | PRESSURE TRIP | PRESSURE TRIP |
| Pressure alarm | | | PRESSURE ALARM | PRESSURE ALARM |
| Thermistor trip | | | THERMISTOR TRIP | THERMISTOR TRIP |
| Thermistor alarm | | | THERMISTOR AL. | THERMISTOR AL. |
| Control fault | | | CONTROL FAULT | CB CNTRL FAULT |
| Load shedding | | | LOAD SHEDDING | LOAD SHEDDING |
| Genset shutdown | | | GENSET SHUTDOWN | GENSET SHUTDOWN |
| De-excitation | | | DE-EXCITATION | DE-EXCITATION |
| Tripping command by automatic transfer | | | AUTO TRANSFER | AUTO TRANSFER |
| **Diagnosis** | **ANSI Code** | | | |
| SF6 fault | | | SF6 LOW | SF6 LOW |
| MET1482 No 1 RTD fault | | | RTD'S FAULT MET1 (1) | RTD'S FAULT NO. 1 (1) |
| MET1482 No 2 RTD fault | | | RTD'S FAULT MET2 (1) | RTD'S FAULT NO. 2 (1) |
| VT supervision | 60FL | Phase VT supervision | VT FAULT | VT FAULT |
| | | Residual VT supervision | VT FAULT Vo | VT FAULT Vr |
| CT supervision | 60 | Main CT supervision | CT FAULT | CT FAULT |
| | | Additional CT supervision | CT' FAULT | CT' FAULT |
| Trip circuit supervision (TCS) fault or mismatching of open/closed position contacts | 74 | | TRIP CIRCUIT | TRIP CKT FAULT |
| Closing circuit fault | | | CLOSE CIRCUIT | CLOSE CIRCUIT |
| Capacitor step matching fault | | | COMP. FLT. STP (1 to 4) | BANK. FLT. STP (1 to 4) |
| Cumulative breaking current monitoring | | | $\Sigma I^2$BREAKING >> | $\Sigma I^2$BREAKING >> |
| Battery monitoring | | | BATTERY LOW (1) | BATTERY LOW (1) |
| Auxiliary power supply monitoring | | Low threshold | LOW POWER SUP. | LOW POWER SUP. |
| | | High threshold | HIGH POWER SUP. | HIGH POWER SUP. |

*(1) RTD FAULT, BATTERY LOW messages: refer to the maintenance chapter.*
*(2) With indication of the faulty phase.*
*(3) With indication of the faulty phase, when used with phase-to-neutral voltage.*

# Local Indication
## ANSI Code 30

| **Functions** | | | **UK English** | **US English** |
|---|---|---|---|---|
| **Protection** | **ANSI Code** | | | |
| Overspeed | 12 | | OVERSPEED | OVERSPEED |
| Underspeed | 14 | | UNDERSPEED | UNDERSPEED |
| Underimpedance | 21B | | UNDERIMPEDANCE | UNDERIMPEDANCE |
| Overexcitation (V/Hz) | 24 | | OVER-FLUXING | OVER EXCITATION |
| Sync-check | 25 | Sync-checked close request in process | SYNC.IN PROCESS | SYNC.IN PROCESS |
| | | Sync-checked close request successful | SYNC. OK | SYNC. OK |
| | | Closing failed, out-of-sync | SYNC. FAILURE | SYNC. FAILURE |
| | | Closing failed, out-of-sync, cause dU | SYNC. FAILED dU | SYNC. FAILED dV |
| | | Closing failed, out-of-sync, cause dPHI | SYNC. FAILED dPhi | SYNC. FAILED dPhi |
| | | Closing failed, out-of-sync, cause dF | SYNC. FAILED dF | SYNC. FAILED df |
| | | Stop closing with sync-check | STOP SYNC. | STOP SYNC. |
| | | Tie closing with sync-check failed | TIE SYNC. FAILED | TIE SYNC. FAILED |
| Undervoltage | 27 | | UNDERVOLTAGE (1) | UNDERVOLTAGE (1) |
| Positive sequence undervoltage | 27D | Positive sequence undervoltage | UNDERVOLTAGE.PS | UNDERVOLTAGE.PS |
| | | Reverse rotation | ROTATION - | REV ROTATION - |
| Third harmonic undervoltage | 27TN/64G2 | | 100% STATOR | 100% STATOR GROUND |
| Active overpower | 32P | | OVER P | OVER POWER |
| Reactive overpower | 32Q | | OVER Q | EXCESS OVER VAR |
| Phase undercurrent | 37 | | UNDER CURRENT | UNDERCURRENT |
| Phase underpower | 37P | | UNDER POWER | UNDER POWER |
| Temperature monitoring | 38/49T | Alarm | OVER TEMP. ALM | OVER TEMP. ALM |
| | | Tripping | OVER TEMP. TRIP | OVER TEMP. TRIP |
| Field loss | 40 | | FIELD LOSS | LOSS OF FIELD |
| Negative sequence / unbalance | 46 | | UNBALANCE I | CURRENT UNBAL |
| Negative sequence overvoltage | 47 | | UNBALANCE U | VOLTAGE UNBAL |
| Excessive starting time, locked rotor | 48/51LR | Excessive starting time | LONG START | LONG START |
| | | Locked rotor in normal operation | ROTOR BLOCKING | JAMMED / STALL |
| | | Locked rotor on start | LOCKED ROT$^{OR}$ | ST$^{RT}$ LOCKED ROT$^{R}$ |
| Thermal overload | 49RMS | Alarm | THERMAL ALARM | THERMAL ALARM |
| | | Tripping | THERMAL TRIP | THERMAL TRIP |
| | | Block closing | START INHIBIT | BLOCKED START |
| Breaker failure | 50BF | | BREAKER FAILURE | BREAKER FAILURE |
| Inadvertent energization | 50/27 | | INADV. ENERGIZ. | INADV. ENERGIZ. |
| Phase overcurrent | 50/51 | | PHASE FAULT (2) | PHASE FAULT (2) |
| Ground fault | 50N/51N | | EARTH FAULT | GROUND FAULT |
| Voltage-restrained overcurrent | 50V/51V | | O/C V REST (2) | O/C V REST (2) |
| Capacitor bank unbalance | 51C | | UNBAL. STP (1 to 4) | UNBAL. STEP (1 to 4) |
| Overvoltage | 59 | | OVERVOLTAGE (1) | OVERVOLTAGE (1) |
| Neutral voltage displacement | 59N | | Vo FAULT | Vr FAULT |
| Restricted ground fault | 64REF | | RESTRIC. EARTH FAULT | RESTRIC. GROUND FAULT |
| Starts per hour | 66 | | START INHIBIT | BLOCKED START |
| Directional phase overcurrent | 67 | | DIR. PHASE FAULT (2) | DIR. PHASE FAULT (2) |
| Directional ground fault | 67N/67NC | | DIR. EARTH FAULT | DIR. GROUND FAULT |
| Pole slip | 78PS | | POLE SLIP | POLE SLIP |
| Recloser | 79 | Cycle x | CYCLE (1 to 4) (3) | SHOT (1 to 4) (3) |
| | | Reclosing successful | CLEARED FAULT | CLEARED FAULT |
| | | Permanent trip | FINAL TRIP | FINAL TRIP |
| Overfrequency | 81H | | OVER FREQ. | OVER FREQ. |
| Underfrequency | 81L | | UNDER FREQ. | UNDER FREQ. |
| Rate of change of frequency | 81R | | ROCOF | df/dt |
| Machine differential | 87M | | DIFFERENTIAL | DIFFERENTIAL |
| Transformer differential | 87T | | DIFFERENTIAL | DIFFERENTIAL |

***(1)** With indication of the faulty phase, when used with phase-to-neutral voltage.*
***(2)** With indication of the faulty phase.*
***(3)** With indication of the protection unit that has initiated the cycle (phase fault, ground fault, ...).*

# Local Indication
ANSI Code 30

## Personalized User Messages

An additional 100 messages can be created using the SFT2841 software. The user can link a message to a logic input, to the result of a logic equation, or to replace a predefined message by a user message.

### User Message Editor in SFT2841

A user message editor is included in the SFT2841 software and can be accessed from the control matrix screen while in the connected or disconnected mode. To access the message editor follow these steps:

**1** display the "Event" tab on the screen: the user messages appear
**2** double-click on one of the messages displayed to activate the user message editor.

### User Message Editor Functions

The Message Editor allows the user to perform the following tasks:

- create and modify user messages in US English or the local language
  - by text input or importing of an existing bitmap file (*.bmp) or by point to point drawing
- delete user messages
- assign predefined or user messages to an event defined in the control matrix:
  - from the control matrix screen, "Events" tab, double-click on the event to be linked to a new message
  - select the new predefined or user message from the messages presented
  - "assign" it to the event.

The same message may be assigned to several events, with no limitations.

## Message Display in SFT2841

- The predefined messages are stored in Sepam™'s memory and are displayed in connected mode. In disconnected mode, the last messages stored in Sepam™ connected mode are displayed.
- The user messages are saved with the other Sepam™ parameters and protection settings and are displayed in connected and disconnected modes.

## Message Processing on the Sepam™ Display

clear

When an event occurs, the related message appears on the Sepam™ display.

The user presses the **clear** key to clear the message and enable normal consultation of all the display.

The user must press the reset key to acknowledge latched events (e.g. protection outputs).

The list of messages remains accessible in the alarm history (⚠ key), in which the last 16 messages are stored. The last 250 messages may be consulted with the SFT2841 software.

To delete the messages stored in the alarm history:

- display the alarm history on the display
- press the **clear** key.

## LED Indication

The 9 yellow LEDs on the front of Sepam™ are assigned by default to the following events:

| LED | Event | Name on Label on Front Panel |
|---|---|---|
| LED 1 | Trip protection 50/51 unit 1 | I>51 |
| LED 2 | Trip protection 50/51 unit 2 | I>>51 |
| LED 3 | Trip protection 50N/51N unit 1 | Io > 51N |
| LED 4 | Trip protection 50N/51N unit 2 | Io >> 51N |
| LED 5 | | Ext |
| LED 6 | | |
| LED 7 | Circuit breaker open (Ia02) | 0 Off |
| LED 8 | Circuit breaker closed (Ia01) | I On |
| LED 9 | Trip by circuit breaker control | Trip |

The default parameter setting can be personalized using the SFT2841 software. LEDs are assigned to events in the "LEDs" tab of the control matrix screen. Editing and printing of personalized labels are proposed in the general characteristics screen.

# Local Control

PE50486

*Local control using the mimic-based UMI*

## Description

Switchgear can be controlled locally using Sepam™ Series 80 units equipped with the mimic-based UMI. The control functions available are:

- selecting the Sepam™ control mode
- viewing device status on the animated mimic diagram
- local control of the opening and closing of all Sepam™ controlled devices

## Selecting the Sepam™ Control Mode

A key-switch on the front of the mimic-based UMI is used to select the Sepam™ control mode. Three modes are available: Remote, Local, or Test.

In **Remote** mode, remote control commands are taken into account. Local control commands are disabled, with the exception of the circuit breaker open command. Remote mode is indicated by the variable V_MIMIC_REMOTE = 1.

In **Local** mode, remote control commands are disabled, with the exception of the circuit breaker open command. Local control commands are enabled. Local mode is indicated by the variable V_MIMIC_LOCAL = 1.

**Test** mode should be selected for tests on equipment, as in during preventive maintenance operations. All functions enabled in Local mode are available in Test mode. No time-tagged events are sent by the communication link. Test mode is indicated by the variable V_MIMIC_TEST = 1.

The Logipam programming software can be used to customize control-mode processing.

## Mimic Diagram and Symbols

A mimic diagram or single-line diagram is a simplified diagram of an electrical installation. It is made up of a fixed background on which symbols and measurements are placed.

The mimic diagram editor integrated in the SFT2841 software can be used to personalize and setup mimic diagrams.

The symbols that make up the mimic-diagram constitute the interface between the mimic-based UMI and the other Sepam™ control functions.

There are three types of symbols:

- **fixed symbol**: represents the electrotechnical devices that are neither animated or controlled, e.g. a transformer
- **animated symbol** with one or two inputs: represents the electrotechnical devices that change on the mimic diagram, depending on the symbol inputs, but cannot be controlled via the Sepam™ mimic-based UMI.
  This type of symbol is used for switch-disconnectors without remote control, for example.
- **controlled symbol** with one or two inputs/outputs: represents the electrotechnical devices that change on the mimic diagram, depending on the symbol inputs, and can be controlled via the Sepam™ mimic-based UMI.

  This type of symbol is used for circuit breakers, for example. The symbol outputs are used to control the electrotechnical device:
  - ☐ directly via the Sepam™ logic outputs
  - ☐ by the switchgear control function
  - ☐ by logic equations or the Logipam program.

# Local Control

## Symbol Animation

Symbols change, depending on the value of their inputs. A graphic symbol represents each state. Animation occurs automatically by changing the symbol each time the state changes.

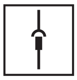
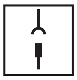
The symbol inputs must be assigned directly to the Sepam™ inputs to indicate the position of the symbolized switchgear.

### Animated Symbols with One Input

"Animated -1 input" and "Controlled -1 input/output" symbols are animated symbols with one input. The value of the input determines the state of the symbol:

- input set to 0 = inactive
- input set to 1 = active

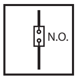
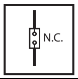
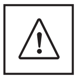
This type of symbol is used for simple presentation of information, for example the racked out position of a circuit breaker.

| Symbol Inputs | Symbol State | Graphic Representation (example) |
|---|---|---|
| Input = 0 | Inactive |  |
| Input = 1 | Active |  |

### Animated Symbols with Two Inputs

"Animated - 2 inputs" and "Controlled - 2 inputs/outputs" symbols are animated symbols with two inputs, one open and the other closed. This is the most common situation in representing switchgear positions.

The symbol has three states,or graphic representations: open, closed, and unknown. The latter occurs when the inputs are not matched. In this case it is impossible to determine the position of the switchgear.

| Symbol Inputs | Symbol State | Graphic Representation (Example) |
|---|---|---|
| Input 1 (open) = 1<br>Input 2 (closed) = 0 | Open |  |
| Input 1 (open) = 0<br>Input 2 (closed) = 1 | Closed |  |
| Input 1 (open) = 0<br>Input 2 (closed) = 0 | Unknown |  |
| Input 1 (open) = 1<br>Input 2 (closed) = 1 | Unknown | |

## Local Control Using a Symbol

"Controlled - 1 input/output" and "Controlled - 2 inputs/outputs" symbols are used to control the switchgear corresponding to the symbol via the Sepam™ mimic-based UMI.

### Control Symbols with Two Outputs

"Controlled - 2 inputs/outputs" symbols have two control outputs for opening and closing of the symbolized device. An command on the mimic-based UMI sends a 300 ms pulse on the controlled output.

### Control Symbols with One Output

"Controlled - 1 input/output" symbols have one control output. The output remains in the last state to which it was commanded. A new command results in a change in the output state.

### Blocking Commands

"Controlled - 1 input/output" and "Controlled - 2 inputs/outputs" symbols have two block inputs that, when set to 1, block opening and closing commands. This makes it possible to create interlocking systems or other command-disabling systems that are taken into account by the UMI.

# Local Control

## Symbol Inputs/Outputs

Depending on the desired operation of the mimic-based UMI, Sepam™ variables must be assigned to the inputs of animated symbols and the inputs/outputs of controlled symbols.

**Sepam™ Variables Assigned to Symbol Inputs**

| Sepam™ Variables | | Name | Use |
|---|---|---|---|
| Logic inputs | | Ixxx | Symbol animation directly based on device positions |
| Outputs of predefined functions | Switchgear control | V_BLOCK_CLOSE | Circuit-breaker operation disabled |
| | Position of key on the front panel of Sepam™ | V_MIMIC_LOCAL,<br>V_MIMIC_REMOTE,<br>V_MIMIC_TEST | ■ Representation of key position<br>■ Operation disabled depending on the control mode |
| | Logic equations or Logipam program | V_MIMIC_IN_1 to V_MIMIC_IN_16 | ■ Representation of Sepam™ internal status conditions<br>■ Cases where operation is disabled |

**Sepam™ Variables to be Assigned to Symbol Outputs**

| Sepam™ Variables | | Name | Use |
|---|---|---|---|
| Logic outputs | | Oxxx | Direct control of devices |
| Inputs of predefined functions | Switchgear control | V_MIMIC_CLOSE_CB<br>V_MIMIC_OPEN_CB | Circuit-breaker control using the switchgear-control function via the mimic-based UMI |
| | Logic equations or Logipam program | V_MIMIC_OUT1 to V_MIMIC_OUT16 | Command processing by logic functions: interlocking, command sequence, etc. |

## Block Diagram

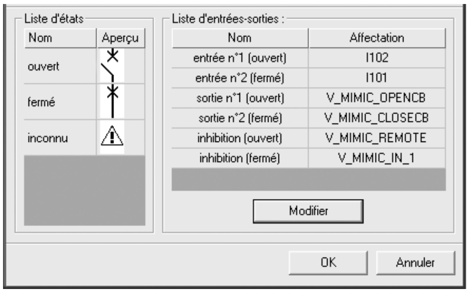
The block diagrams below present the functions ensured by the controlled symbols, based on two examples.

Voluntary user control commands (selection of the device to be controlled in the mimic diagram and action on a control key) are represented in the block diagrams by the following icons:

Ⓞ: open command

Ⓘ: close command

PE50416



Liste d'états

| Nom | Aperçu |
|---|---|
| ouvert | |
| fermé | |
| inconnu | |

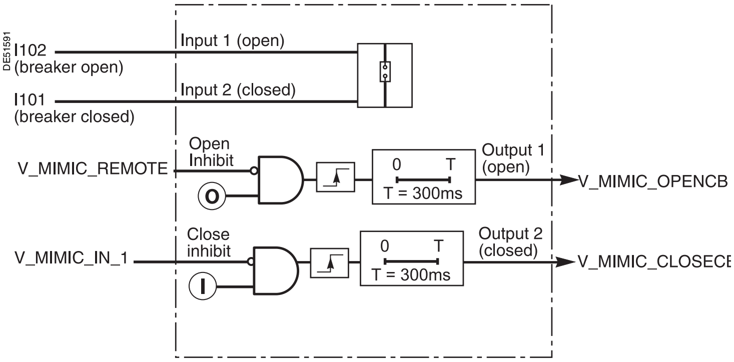
Liste d'entrées-sorties :

| Nom | Affectation |
|---|---|
| entrée n°1 (ouvert) | I102 |
| entrée n°2 (fermé) | I101 |
| sortie n°1 (ouvert) | V_MIMIC_OPENCB |
| sortie n°2 (fermé) | V_MIMIC_CLOSECB |
| inhibition (ouvert) | V_MIMIC_REMOTE |
| inhibition (fermé) | V_MIMIC_IN_1 |

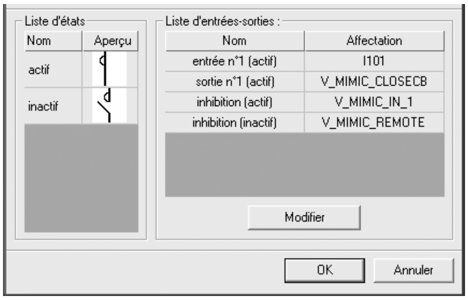
Modifier
OK
Annuler

*SFT2841: example of the logic input / output assignment of a symbol with two outputs.*

**Local Control using Symbols with Two Outputs**


DE51591
I102
(breaker open)
I101
(breaker closed)
Input 1 (open)
Input 2 (closed)
V_MIMIC_REMOTE
Open
Inhibit
O
0
T
T = 300ms
Output 1
(open)
V_MIMIC_OPENCB
V_MIMIC_IN_1
Close
inhibit
I
0
T
T = 300ms
Output 2
(closed)
V_MIMIC_CLOSECB

PE50415



Liste d'états

| Nom | Aperçu |
|---|---|
| actif | |
| inactif | |

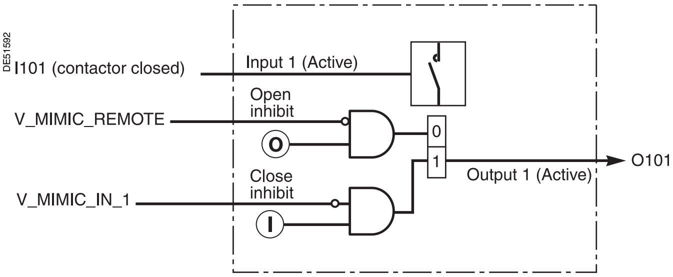
Liste d'entrées-sorties :

| Nom | Affectation |
|---|---|
| entrée n°1 (actif) | I101 |
| sortie n°1 (actif) | V_MIMIC_CLOSECB |
| inhibition (actif) | V_MIMIC_IN_1 |
| inhibition (inactif) | V_MIMIC_REMOTE |

Modifier
OK
Annuler

*SFT2841: example of the logic input / output assignment of a symbol with one output.*

**Local Control using a Symbol with One Output**


DE51592
I101 (contactor closed)
Input 1 (Active)
V_MIMIC_REMOTE
Open
inhibit
O
V_MIMIC_IN_1
Close
inhibit
I
0
1
Output 1 (Active)
O101

# Control Matrix

## Description

The control matrix is used for assigning the logic outputs and LEDs to data produced by the protection functions, control logic, and logic inputs.

Each column creates a logic OR between all the lines selected. The matrix can also be used to display the alarms associated with the data. It guarantees the consistency of the parameter setting with the predefined functions.

The following data are managed in the control matrix and can be set using the SFT2841 software tool.

## Control Matrix Inputs

| "Protection" Button | Meaning | Comments |
|---|---|---|
| All application protection functions | Protection tripping output and additional outputs when applicable | |
| **"Inputs" Button** | | |
| Logic inputs I101 to I114 | According to configuration | If first MES120 module is configured |
| Logic inputs I201 to I214 | According to configuration | If second MES120 module is configured |
| Logic inputs I301 to I314 | According to configuration | If third MES120 module is configured |
| **"Equations" Button** | **Meaning** | **Comments** |
| V1 to V20 | Logic equation editor outputs | |
| **"Logipam" Button** | **Meaning** | **Comments** |
| MAT001 to MAT128 | Logipam output variables to the control matrix | Only the variables actually used in the Logipam program are displayed |
| **"Logic" Button** | **Meaning** | **Comments** |
| **Switchgear Control** | | |
| Closing | Closing by switchgear control function | By default on O3. Only available if switchgear control is in circuit breaker mode |
| Tripping | Tripping by switchgear control function | Forced on O1, if switchgear control is in circuit breaker mode |
| Block closing | Block by switchgear control function | By default on O2. Only available if switchgear control is in circuit breaker mode |
| Contactor control | Contactor control | Forced on O1, if switchgear control is in circuit breaker mode |
| Pick-up | Logic OR of the instantaneous output of all protection units with the exception of protection units 38/49T, 48/51LR, 49 RMS, 64G2/27TN, 66. | |
| Drop-out | A protection unit time delay counter has not yet gone back to 0. | |
| **Zone Selective Interlocking** | | |
| Zone selective Interlocking trip | Tripping command sent by zone selective interlocking function | Only when zone selective interlocking function is used without switchgear control function |
| Blocking send 1 | Sending of blocking signal to next Sepam™ in zone selective interlocking chain 1 | By default on O102. |
| Blocking send 2 | Sending of blocking signal to next Sepam™ in zone selective interlocking chain 2 | By default on O103 |
| **Motor/Generator Control** | | |
| Load shedding | Sending of a load shedding command | Motor application |
| Genset shutdown | Sending of a prime mover shutdown command | Generator application |
| De-excitation | Sending of a de-excitation command | Generator application |
| **Recloser** | | |
| Recloser in service | The recloser is in service | |
| Reclosing successful | The recloser has successfuly reclosed | Pulse type output |
| Permanent trip | The circuit breaker is permanently open after the reclosing cycles | Pulse type output |
| Recloser ready | The recloser is ready to operate | |
| Recloser step 1 | Step 1 in progress | |
| Recloser step 2 | Step 2 in progress | |
| Recloser step 3 | Step 3 in progress | |
| Recloser step 4 | Step 4 in progress | |
| Closing by recloser | A closing command is given by the recloser | |

| "Logic" Button | Meaning | |
|---|---|---|
| **Diagnosis** | | |
| TCS fault | Trip circuit fault | |
| CCS fault | Closing circuit fault | |
| TC / breaker position discrepancy | Discrepancy between the last state commanded by the remote monitoring and control system and the position of the circuit breaker | |
| Breaker monitoring | A circuit breaker or contactor open or close command has not been executed | |
| Reverse phase rotation | Reverse voltage rotation due to a wiring error | |
| Additional-phase reverse rotation | Reverse rotation of additional phase voltages due to a wiring error | |
| Disturbance recording blocked | Disturbance recording blocked | |
| Cumulative breaking current monitoring | Overshooting of the cumulative breaking current set point | |
| Low auxiliary voltage threshold | The auxiliary voltage is below the low threshold | |
| High auxiliary voltage threshold | The auxiliary voltage is above the high threshold | |
| Low battery fault | Battery low or absent | |
| MET1482 No 1 fault<br>MET1482 No 2 fault | Hardware problem on an MET 1482 module (module 1 or 2) or on an RTD | |
| Watchdog | Monitoring of Sepam™ operation | Always on O5 if used |
| **CT Supervision** | | |
| Main CT fault | I current input CT fault | |
| Additional CT fault | I' current input CT fault | |
| **VT Supervision** | | |
| Main VT fault, phase channel | V voltage input phase VT fault | |
| Main VT fault, residual channel | Vr voltage input residual VT fault | |
| Additional VT fault, phase channel | V' voltage input phase VT fault | |
| Additional VT fault, residual channel | V'r voltage input residual VT fault | |
| **Sync-Check** | | |
| Closing with sync-check | Circuit breaker close request with sync-check by the ANSI 25 function has been initiated | Switchgear control with sync-check function |
| Closing with sync-check completed | Breaker closing with sync-check by the ANSI 25 function successful | Switchgear control with sync-check function |
| Closing failed, out-of-sync | Synchronism conditions too short to enable breaker closing | Switchgear control with sync-check function |
| Closing failed, out-of-sync, cause dU | Breaker closing blocked because sources are out-of-sync due to an excessive voltage difference | Switchgear control with sync-check function |
| Closing failed, out-of-sync, cause dPHI | Breaker closing blocked because sources are out-of-sync due to an excessive phase difference | Switchgear control with sync-check function |
| Closing failed, out-of-sync, cause dF | Breaker closing blocked because sources are out-of-sync due to an excessive frequency difference | Switchgear control with sync-check function |
| Stop closing with sync-check | A sync-checked circuit breaker close request has been interrupted | Switchgear control with sync-check function |
| **Automatic Transfer** | | |
| Tie closing with sync-check failed | The tie close request initiated by automatic transfer has failed because the sources are out-of-sync | |
| Tripping by automatic transfer | Breaker tripping initiated by automatic transfer (tripping is performed by the switchgear control function) | |
| Tripping by 2/3 or 1/2 logic | Breaker tripping initiated by 2/3 or 1/2 logic (tripping is performed by the switchgear control function) | |
| NO circuit breaker closing | Normally open circuit breaker close command for automatic transfer function | |
| Breaker closing ready | Indication that breaker closing is possible to return to normal operation | |
| Tie closing | Tie closing command for automatic transfer function | |
| Tie closing ready | Indication that tie breaker closing is possible to return to normal operation | |
| Tie Breaker tripping | Tie tripping command for automatic transfer function | |
| **Control of Capacitor Banks** | | |
| Tripping of capacitor step x | Capacitor step x tripping output | |
| Closing of capacitor step x | Capacitor step x closing output | |
| Capacitor step x position fault | Capacitor step x positions mismatched | |
| Automatic capacitor step control | Capacitor steps in automatic control mode | |
| Manual capacitor step control | Capacitor steps in manual control mode | |

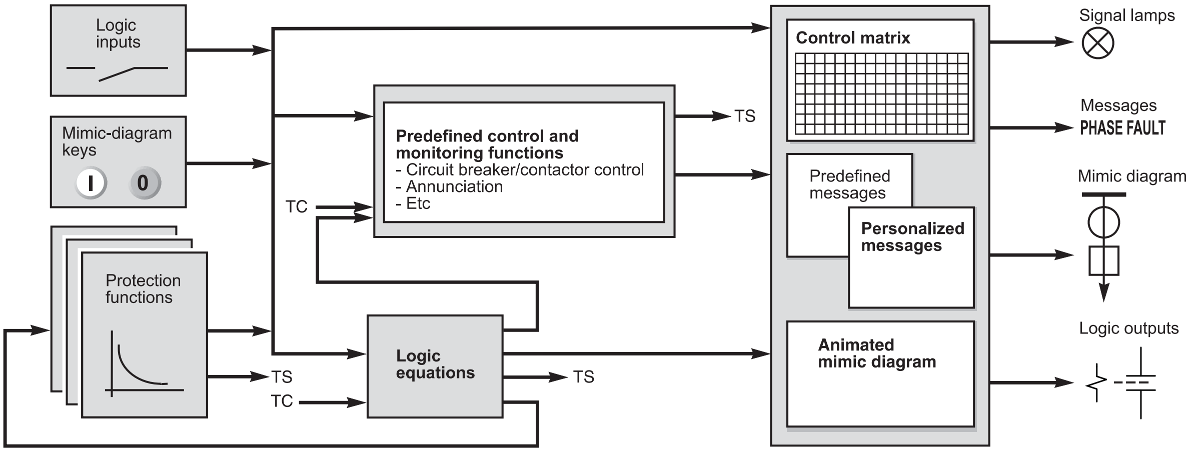
# Logic Equations

*Adaptation of the predefined control and monitoring functions by the addition of simple logic functions.*

## Use

This function can be used to configure simple logic functions by combining data received from the protection functions, logic inputs, remote control commands, or the mimic-based UMI.
By using logic operators (AND, OR, XOR, NOT) and timers, new processing operations and indications may be added to the existing ones.
The logic functions produce outputs that can be used:

- in the matrix to control output relays, switch on a LED, or display new messages
- in the protection functions to create, for example, new block or reset conditions
- in the main predefined control and monitoring functions to complete processing operations or add new cases of tripping or genset shutdown, for example
- for mimic diagram animation.


DE51593
Logic inputs
Mimic-diagram keys
I
0
Protection functions
TS
TC
TC
TS
Predefined control and monitoring functions
- Circuit breaker/contactor control
- Annunciation
- Etc
Logic equations
TS
Control matrix
Predefined messages
Personalized messages
Animated mimic diagram
Signal lamps
Messages
PHASE FAULT
Mimic diagram
Logic outputs

## Logic Function Configuration

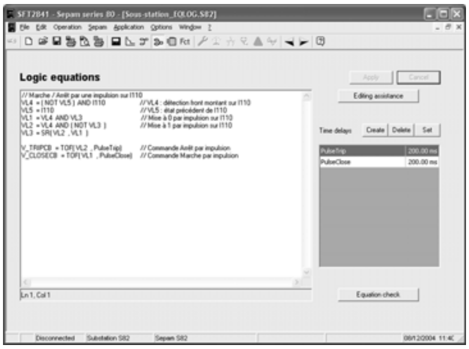
Logic functions are entered in text format in the SFT2841 equation editor. Each line includes a logic operation, the result of which is assigned to a variable.

Example:

**Va = P5051_2_3 OR Ia02**.

The variable Va is assigned the result of the logic OR operation involving the value from protection function 50/51 and logic input Ia02. The variables may be used for other operations or as outputs to produce actions in the control matrix, protection functions or predefined control and monitoring functions.

A program is a series of lines executed sequentially every 14 ms. A data input assistance tool provides quick access to each equation editor operator and variables.

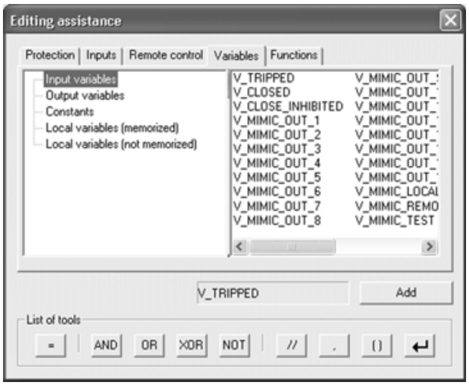

PE50460
SFT2841 - Sepam series 80 - [Sous-station_EQLOG.S82]
File Edit Operation Sepam Application Options Window ?
Logic equations
Apply
Cancel
Editing assistance
Time delays
Create
Delete
Set
Equation check
Ln 1, Col 1
Disconnected
Substation S82
Sepam S82
08/12/2004 11:4

```
// Marche / Arrêt par une impulsion sur I110
VL4  = ( NOT VL5 ) AND I110            // VL4 : détection front montant sur I110
VL5  = I110                            // VL5 : état précédent de I110
VL1  = VL4 AND VL3                     // Mise à 0 par impulsion sur I110
VL2  = VL4 AND ( NOT VL3 )             // Mise à 1 par impulsion sur I110
VL3  = SR( VL2 , VL1 )

V_TRIPCB  = TOF( VL2 , PulseTrip)      // Commande Arrêt par impulsion
V_CLOSECB  = TOF( VL1 , PulseClose)    // Commande Marche par impulsion
```

| | |
|---|---|
| PulseTrip | 200.00 ms |
| PulseClose | 200.00 ms |

*SFT2841: logic equation editor.*


PE50461
Editing assistance
Protection
Inputs
Remote control
Variables
Functions
Input variables
Output variables
Constants
Local variables (memorized)
Local variables (not memorized)
Add
List of tools
=
AND
OR
XOR
NOT
//
,
( )
↵

```
V_TRIPPED            V_MIMIC_OUT_
V_CLOSED             V_MIMIC_OUT_
V_CLOSE_INHIBITED    V_MIMIC_OUT_
V_MIMIC_OUT_1        V_MIMIC_OUT_
V_MIMIC_OUT_2        V_MIMIC_OUT_
V_MIMIC_OUT_3        V_MIMIC_OUT_
V_MIMIC_OUT_4        V_MIMIC_OUT_
V_MIMIC_OUT_5        V_MIMIC_OUT_
V_MIMIC_OUT_6        V_MIMIC_LOCAL
V_MIMIC_OUT_7        V_MIMIC_REMO
V_MIMIC_OUT_8        V_MIMIC_TEST
```

V_TRIPPED

*SFT2841: data input assistance tool.*

## Description of Operations

### Operators

- **=**: assignment of a result
  **Vb = VL3** //Vb is assigned the value of VL3
- **NOT**: logic inversion
  **VL1 = NOT VL2** // VL1 is assigned the opposite logic state of VL2
- **OR**: logic OR
  **Va = VL3 OR I103** // Va is assigned state 1 if VL3 or I103 are in state 1
- **AND**: logic AND
  **VV3 = VL2 AND VVa** // VV3 is assigned state 1 if VL2 and VV1 are in state 1
- **XOR**: exclusive OR
  **V3 = VL1 XOR VL2 //** V3 is assigned state 1 if only one of the variables VL1 or VL2 is in state 1.
  This is equivalent to **V3 = (Va AND (NOT Vb)) OR (Vb AND (NOT Va))**
- **//**: commentary
  The characters on the right are not processed
- **(,)**: the operations may be grouped between brackets to indicate the order in which they are carried out
  **V1 = (VL3 OR VL2) AND I213**.

**Functions**

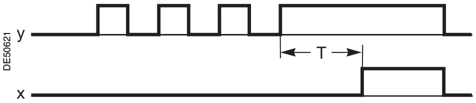
- x = **SR**(y, z): bistable with priority to Set
  x is set to 1 when y is equal to 1
  x is set to 0 when z is equal to 1 (and y is equal to 0)
  otherwise x is not changed.

**V1 = SR(I104, I105)** // I104 sets V1 to 1, I105 sets V1 to 0

- **LATCH**(x, y, …): latching of variables x, y, ...

The variables are maintained constantly at "1" after being initially set. They are reset to "0" when Sepam™ is reset (reset button, external input or remote control command).

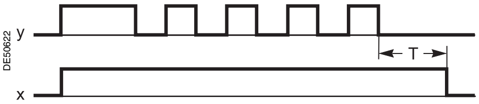
The LATCH function accepts as many parameters as the number of variables that the user wishes to latch. It applies to the entire program, whatever the position of LATCH in the program. For easier reading, it is advisable to put it at the beginning of the program.
**LATCH(V1, VL2, VV3)** // V1, VL2 and VV3 are latched. Once they are set to 1, only a Sepam™ reset can set them back to 0



*x = **TON**(y, t).*

- x = **TON**(y, t): "on" delay timer

The variable x goes to 1 t ms after variable y goes to 1.
**V1 = TON(I102.2000)** // used to filter input I102 which must be present for
// 2 s to be taken into account in V1



*x = **TOF**(y, t).*

- x = **TOF**(y, t) : "off" delay timer.

The variable x goes to 0 t ms after variable y goes to 0).

**VL2 = TOF(VL1, 100)** // VL2 stays at 1 for 100 ms after VL1
// goes back to 0

- x = **PULSE**(s, i, n): time-tagger

Used to generate n periodic pulses, separated by an interval i as of the starting time s
s is expressed in hours:minutes:seconds
i is expressed in hours:minutes:seconds
n is a whole number (n = -1: repeated until the end of the day).
**V1 = PULSE (8:30:00, 1:0:0, 4)** will generate 4 pulses at 1-hour intervals at 8 h 30, 9 h 30, 10 h 30 and 11 h 30. This will be repeated every 24 hours.
The pulses last for a 14 ms cycle. V1 is assigned the value of 1 during the cycle.
If necessary, V1 may be extended using the **TOF, SR** or **LATCH** functions.

PE50160
Time delays
Create
Delete
Set

start 200.00 ms

*SFT2841: timer editor.*

**Timer values**

A timer editor is used to give a name and value to each timer. The name may then be used in the **TON** and **TOF** functions. The timer value may therefore be adjusted without changing the program content.

**V1 = TON (VL1, start)** // start set to 200 ms in the timer editor.

**Maximum number of functions**

The number of time delays (**TON**, **TOF**) and pulse commands (**PULSE**) is globalized and may not be more than 16.

There is no limitation for the **SR** and **LATCH** functions.

## Description of Variables

- **input variables**: come from the protection functions, logic inputs or predefined control functions. They may only appear on the right of the = sign
- **output variables**: produced by the equation editor to generate actions in the matrix, protection functions or predefined control functions
- **local variables**: intended for intermediary calculations and are not available outside the logic equation editor.

# Logic Equations

## Input vVariables

| Type | Syntax | Example / Meaning |
|---|---|---|
| Logic inputs | Ixxx | I101: input 1 of MES120 No 1 module<br>I312 : input 12 of MES120 No 3 module |
| Protection function outputs | Pnnnn_x_y<br>nnnn: ANSI code<br>x: unit<br>y: data | P50/51_2_1 : Protection 50/51, unit 2, delayed output.<br>The protection function output data numbers are given in the characteristics of each function and may be accessed using the data input assistance tool. |
| Remote control commands | TC1 to TC64 | Pulse type value (duration of one 14 ms cycle) of remote control commands received |
| Predefined control function outputs | V_TRIPPED | Tripping command present at switchgear control function output |
| | V_BLOCK_CLOSE | Block closing command present at switchgear control function output |
| | V_CLOSED | Closing command present at switchgear control function output |
| Mimic-based UMI outputs | V_MIMIC_OUT_1 to V_MIMIC_OUT_16 | Variables that may be assigned to the mimic diagram symbol outputs and that change values when control commands are transmitted from the mimic-based UMI |
| | V_MIMIC_LOCAL<br>V_MIMIC_TEST,<br>V_MIMIC_REMOTE | Position of the key on the mimic-based UMI |

## Output Variables

| Type | Syntax | Example / Meaning |
|---|---|---|
| Outputs to matrix | V1 to V20 | They may initiate LEDs, logic outputs or messages in the matrix. |
| Protection function inputs | Pnnnn_x_y<br>nnn: ANSI code<br>x: unit<br>y: data | P50N/51N_6_113: Protection 50N/51N, unit 6, block command.<br>The protection function output data numbers are given in the characteristics of each function and may be accessed using the data input assistance tool. |
| Predefined control function inputs | V_TRIPCB | Tripping of circuit breaker (contactor) by the switchgear control function. Used to adapt tripping and recloser activation conditions. |
| | V_BLOCKCLOSE | Block circuit breaker (contactor) closing by the switchgear control function. Used to add circuit breaker (contactor) block closing conditions. |
| | V_CLOSECB | Closing of circuit breaker (contactor) by the switchgear control function. Used to generate a circuit breaker (contactor) close command based on a particular condition. |
| | V_SHUTDOWN | Shutdown of genset prime mover. Used to adapt cases of genset shutdown |
| | V_DE_EXCITATION | Generator de-excitation<br>Used to adapt cases requiring generator de-excitation |
| | V_FLAGREC | Data saved in disturbance recording.<br>Used to save a specific logic state in addition to those already present in disturbance recording. |
| | V_RESET | Sepam™ reset |
| | V_CLEAR | Clearing of alarms present |
| | V_BLOCK_RESET_LOCAL | Block Sepam™ reset by UMI Reset key. |
| | V_CLOSE_NOCTRL | Breaking device closing enabled without sync-check.<br>Used to adapt the Switchgear control function |
| | V_TRIP_STP1 to V_TRIP_STP4 | Tripping of capacitor steps 1 to 4.<br>Used to adapt the Capacitor step control function |
| | V_CLOSE_STP1 to V_CLOSE_STP4 | Closing of capacitor steps 1 to 4.<br>Used to adapt the Capacitor step control function |
| | V_TRANS_ON_FLT | Automatic transfer command on fault.<br>Used to adapt automatic transfer |
| | V_TRANS_STOP | Stopping automatic transfer<br>Used to adapt automatic transfer |

## Local Variables, Constants

| Type | Syntax | Example / Meaning |
|---|---|---|
| Local variables stored | VL1 to VL31 | The values of these variables are saved in the event of an auxiliary power outage and are restored when Sepam™ starts again. |
| Local variables not stored | VV1 to VV31 | The values of these variables are not saved in the event of an auxiliary power outage. They are assigned the value of 0 when Sepam™ starts. |
| Constants | K_1, K_0 | Value not modifiable<br>K_1: always 1<br>K_0 : always 0 |

# Logic Equations

### Processing in the Event of Auxiliary Power Outage

All the variables, with the exception of the variables VVx, are saved in the event of a Sepam™ auxiliary power outage. The states of the variables are restored when the power is recovered, allowing the states produced by **LATCH**, **SR** or **PULSE** type memory operators to be saved.

### Special Cases

- brackets must be used in expressions that comprise different **OR, AND, XOR or NOT** operators:
  - ☐ **V1 = VL1 AND I102 OR P27/27S_1_1. //** expression incorrect
  - ☐ **V1 = (VL1 AND I102) OR P27/27S_1_1. //** expression correct
  - ☐ **V1 = VL1 OR I102 OR P27/27S_1_1. //** expression correct
- protection input/output variables (Pnnn_x_y) may not be used in the **LATCH** function
- function parameters may not be expressions:
  - ☐ **VL3 = TON ((V1 AND V3), 300) //** expression incorrect
  - ☐ VL4 = V1 AND V3
  - ☐ **VL3 = TON (VL4, 300) //** correct.

### Use Limit

The number of operators and functions (**OR, AND, XOR, NOT, =, TON, TOF, SR, PULSE** is limited to 200.

## Examples of Applications

The following are some application examples.

1 ***Latching the recloser permanent trip signal***. By default, this signal is of the pulse type at the recloser output. If required by operating conditions, it may be latched as follows:
   **LATCH (V1) //** V1 may be latched
   **V1 = P79_1_204 //** recloser "permanent trip" output.
   V1 may then control a LED or output relay in the matrix.

2 ***Latching an LED without latching the protection function***. Certain operating conditions call for the latching of indications on the front panel of Sepam™, without latching of the tripping output O1.
   **LATCH (V1, V2) //** V1 and V2 may be latched
   **V1 = P50/51_1_1 OR P50/51_3_1 //** tripping, units 1 and 3 of protection 50/51
   **V2 = P50/51_2_1 OR P50/51_4_1 //** tripping, units 2 and 4 of protection 50/51
   V1 and V2 must be configured in the matrix to control 2 front panel LEDs.

3 ***Circuit breaker tripping if input I113 is present for more than 300 ms***.
   **V_TRIPCB = TON (I113, 300)**.

4 ***Live line work (example 1).*** If work is underway with power on (indicated by input I205), the relay behavior is to be changed as follows:
   **a)** circuit breaker tripping by the instantaneous output of protection 50/51 unit 1 or 50N/51N unit 1 AND if input I205 is present:
   **V_TRIPCB = (P50/51_1_1 OR P50N/51N_1_1) AND I205**
   **b)** Block recloser:
   **P79_1_113 = I205**

5 ***Live line work (example 2).*** The user wishes to block protection functions 50N/51N and 46 by an input I204:
   **P50N/51N_1_113 = I204**
   **P46_1_113 = I204**

6 ***Validation of a 50N/51N protection function by logic input I210.*** A 50N/51N protection function with a very low threshold must only initiate tripping of the circuit breaker if it is validated by an input. The input comes from a relay which gives a very accurate measurement of the neutral point current:
   **V_TRIPCB = P50N/51N_1_3 AND I210**

7 ***Block circuit breaker closing if thermal alarm thresholds are overrun.*** The temperature protection function 38/49T supplies 16 alarm bits. If one of the first three bits is activated (1 state), the user wishes to block circuit breaker closing
   **V_BLOCKCLOSE = P38/49T_1_10 OR P38/49T_2_10 OR P38/49T_3_10**

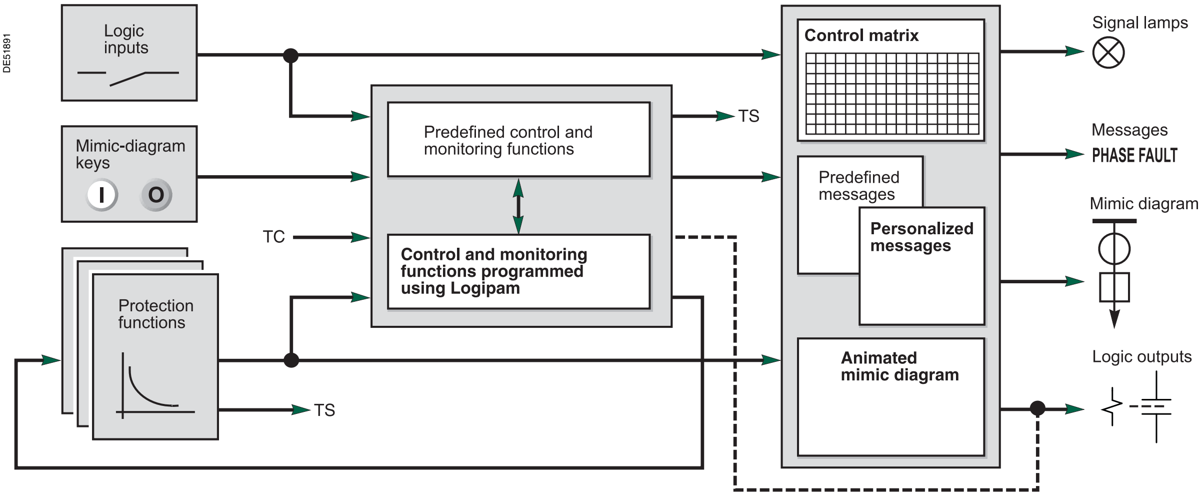
8 Remote control command to block protection 50/51 unit 1.
   **VL1=SR(TC63,TC64) //** TC63 set block, TC64 reset blocking
   **P50/51_1_113 = VL1 //** VL1 is stored in the event of an auxiliary power outage.

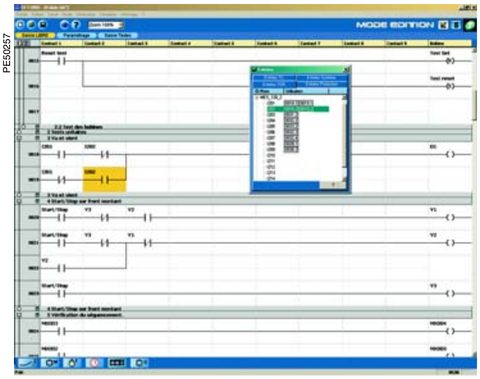
# Customized Functions Using Logipam

The SFT2885 programming software (Logipam) can be used to enhance Sepam™ by programming specific control and monitoring functions.

**Only the Sepam™ Series 80 with a cartridge containing the Logipam SFT080 option can run the control and monitoring functions programmed by Logipam.**

## Operating principle


DE51891
Logic inputs
Mimic-diagram keys
I
O
TC
Protection functions
TS
Predefined control and monitoring functions
TS
Control and monitoring functions programmed using Logipam
Control matrix
Predefined messages
Personalized messages
Animated mimic diagram
Signal lamps
Messages
PHASE FAULT
Mimic diagram
Logic outputs


PE50257
MODE EDITION

SFT2885: Logipam programming software.

## Logipam Programming Software

The Logipam SFT2885 programming software can be used to:
- adapt predefined control and monitoring functions
- program specific control and monitoring functions, either to replace the predefined versions or to create completely new functions, to provide all the functions required by the application.

It consists of:
- a ladder-language program editor used to address all Sepam™ data and to program complex control functions
- a simulator for complete program debugging
- a code generator to run the program on Sepam™.

The ladder-language program and the data used can be documented and a complete file can be printed.

Offering more possibilities than the logic-equation editor, Logipam can be used to create the following functions :
- specific automatic transfer functions
- motor starting sequences.

The functions programmed by Logipam cannot be combined with functions adapted by the logic-equation editor in a given Sepam™.

The Logipam program uses the input data from:
- protection functions
- logic inputs
- remote control commands
- local control commands transmitted by the mimic-based UMI.

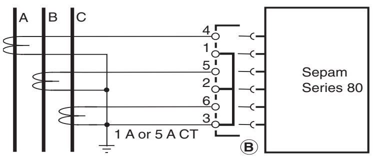
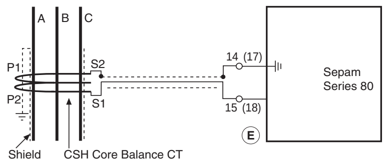
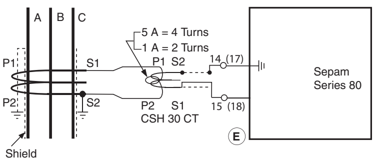
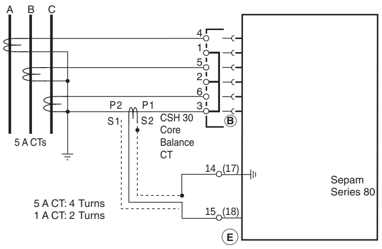
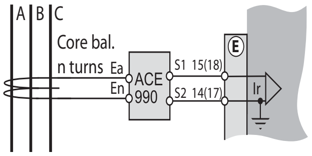
The result of Logipam processing can be:
- assigned to a logic output, directly or via the control matrix
- assigned to a LED or message via the control matrix
- transmitted by the communication link, as a new remote indication
- used by the predefined control and monitoring functions
- used to block or reset a protection function.

# Contents

**Ground Fault Current** **262**

**Function Settings** **264**

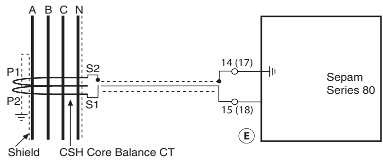
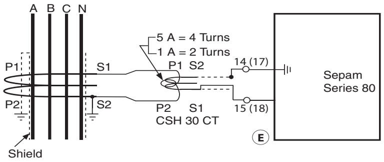
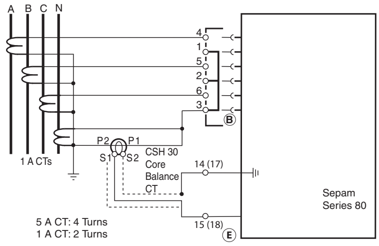
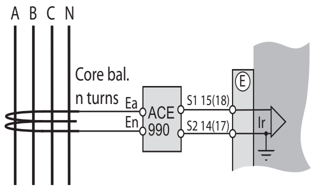
# Ground Fault Current
## Measurement Method Summary without Neutral

| Method Number | Measurement Method | Setting Range | Zero Sequence CT | Connections | Residual Current Setting | Remark |
|---|---|---|---|---|---|---|
| 1A (applies for LPCT also) | Internal Phase Current Summation | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | None |  A<br>B<br>C<br>4<br>1<br>5<br>2<br>6<br>3<br>Sepam Series 80<br>1 A or 5 A CT<br>B | "3I Sum" | Sepam Series 80 Considers INr=IN |
| 2A | Specific CSH Zero Sequence CT On 2 A Input Rating | DT=0.2 A to 30 A<br>IDMT=0.2 A to 2 A | CSH 120<br>CSH 200 |  A<br>B<br>C<br>P1<br>P2<br>S2<br>S1<br>14 (17)<br>15 (18)<br>Sepam Series 80<br>E<br>Shield<br>CSH Core Balance CT | "2 A Rated CSH" (2 A Core Bal. CT) | Sepam Series 80 Considers INr=2 A |
| 3A | Specific CSH Zero Sequence CT on 5 A Input Rating | DT=0.5A to 75A<br>IDMT=0.5A to 7.5A | CSH 120<br>CSH 200 | | "5 A Rated CSH" (5 A zero sequence CT) | Ino=5A |
| 4A | Specific CSH Zero Sequence CT On 20 A Input Rating | DT=2 A to 300 A<br>IDMT=2 A to 20 A | CSH 120<br>CSH 200 | | "20 A Rated CSH (20 A Core Bal. CT) | Sepam Series 80 Considers INr=20 A |
| 5A* | Standard 1A or 5A CT | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | 1 A/5 A CT Zero Sequence CT + CSH 30 Aux CT as interface |  A<br>B<br>C<br>5 A = 4 Turns<br>1 A = 2 Turns<br>P1<br>S1<br>P1 S2<br>14 (17)<br>P2<br>S2<br>P2 S1<br>CSH 30 CT<br>15 (18)<br>Sepam Series 80<br>E<br>Shield | "1 A CT + CSH" or 5 ACT + CSH | Primary Rated Current: 1 A to 6.25 kA, INr=IN |
| 5A (Sensitive) | Standard 5A or 1A CT | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | 5 A/1 A CT Zero Sequence CT + CSH 30 Aux CT as interface | | "5 A CT + CSH" (or 1 A CT + CSH) "sensitivity X10 | Primary Rated Current: 1 A to 6.25 kA, INr=IN/10 |
| 6A* | External Sum of Phase CT Secondaries (1 A or 5 A) | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | CSH 30 Zero Sequence CT as Interface |  A<br>B<br>C<br>4<br>1<br>5<br>2<br>6<br>3<br>P2<br>P1<br>S1<br>S2<br>CSH 30 Core Balance CT<br>B<br>5 A CTs<br>14 (17)<br>15 (18)<br>Sepam Series 80<br>5 A CT: 4 Turns<br>1 A CT: 2 Turns<br>E | "1 A CT + CSH" or "5 A CT + CSH" | Set Sepam Series 80 For INr=IN (Primary Rated Current: 1 A to 6.25 kA) |
| 6A (Sensitive) | External Sum of Phase CT Secondaries (1 A or 5 A) | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | CSH 30 Zero Sequence CT as Interface | | "1 A CT + CSH (or 5 A CT + CSH) sensitivity X10 | INr=IN/10 (Ipri=1 A to 6.25 kA) |
| 7A | Standard 1 A CT or 5 A CT | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | 1 A/5 A Zero Sequence CT + ACE 990 |  A<br>B<br>C<br>Core bal.<br>n turns<br>Ea<br>En<br>ACE 990<br>S1 15(18)<br>S2 14(17)<br>E<br>Ir | 5 A CT + ACE<br>1 A CT + ACE | INr=k x N<br>N=CT turns .00578 ≤ K ≤ .26316 |

***See alternate CSH30 secondary connection in the Sepam Series 80 *Installation, Use, Commissioning and Maintenance* manual.**

***Note:*** *INr should be thought of as a relay input port for ground fault protection. This port can accept residually connected phase ct's and therefore measure positive, negative and zero sequence components. This port can also accept a zero sequence ct which measures only true zero sequence (no positive or negative sequence). So the port name INr is just that a port name. What kind of current (positive, negative or zero sequence) depends on the type of CTs used)*

# **Ground Fault Current** Measurement Method Summary with Neutral

| Method Number | Measurement Method | Setting Range | Zero Sequence CT | Connections | Residual Current Setting | Remark |
|---|---|---|---|---|---|---|
| 2B | Specific CSH Zero Sequence CT On 2 A Input Rating | DT=0.2 A to 30 A<br>IDMT=0.2 A to 2 A | CSH 120<br>CSH 200 |  A B C N<br>P1<br>P2<br>S2<br>S1<br>14 (17)<br>15 (18)<br>Sepam Series 80<br>E<br>Shield<br>CSH Core Balance CT | “2 A Rated CSH” (2 A Core Bal. CT) | Sepam Series 80 Considers INr=2 A |
| 3B | Specific CSH Zero Sequence CT on 5 A Input Rating | DT=0.5A to 75A<br>IDMT=0.5A to 7.5A | CSH 120<br>CSH 200 | | “5 A Rated CSH” (5 A zero sequence CT) | INr=5A |
| 4B | Specific CSH Zero Sequence CT On 20 A Input Rating | DT=2 A to 300 A<br>IDMT=2 A to 20 A | CSH 120<br>CSH 200 | | “20 A Rated CSH (20 A Core Bal. CT) | Sepam Series 80 Considers INr=20 A |
| 5B* | Standard 1 A CT or 5 A CT | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | 1 A/5 A CT Zero Sequence CT + CSH 30 Aux CT as interface |  A B C N<br>5 A = 4 Turns<br>1 A = 2 Turns<br>P1<br>S1<br>P1 S2<br>14 (17)<br>Sepam Series 80<br>P2<br>S2<br>P2 S1<br>CSH 30 CT<br>15 (18)<br>E<br>Shield | “1 A CT + CSH” or 5 ACT + CSH | Primary Rated Current: 1 A to 6.25 kA, INr=IN |
| 5B (Sensitive) | Standard 5 A CT or 1 A CT | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | 5 A/1 A CT Zero Sequence CT + CSH 30 Aux CT as interface | | “5 A CT + CSH” (or 1 A CT + CSH) “sensitivity X10 | Primary Rated Current: 1 A to 6.25 kA, INr=IN/10 |
| 6B* | External Sum of Phase CT Secondaries (1 A or 5 A) | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | CSH 30 Zero Sequence CT as Interface |  A B C N<br>4<br>1<br>5<br>2<br>6<br>3<br>B<br>P2<br>P1<br>S1<br>S2<br>CSH 30 Core Balance CT<br>1 A CTs<br>14 (17)<br>15 (18)<br>Sepam Series 80<br>5 A CT: 4 Turns<br>1 A CT: 2 Turns<br>E | “1 A CT + CSH” or “5 A CT + CSH” | Set Sepam Series 80 For INr=IN (Primary Rated Current: 1A to 6.25 kA) |
| 6B (Sensitive) | External Sum of Phase CT Secondaries (1 A or 5 A) | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | CSH 30 Zero Sequence CT as Interface | | “1 A CT + CSH (or 5 A CT + CSH) sensitivity X10 | INr=IN/10 (Ipri=1 A to 6.25 kA) |
| 7B | Standard 1 A CT or 5 A CT | DT=0.1 to 15 INr<br>IDMT=0.1 to INr | 1 A/5 A Zero Sequence CT + ACE 990 |  A B C N<br>Core bal.<br>n turns<br>Ea<br>En<br>ACE 990<br>S1 15(18)<br>S2 14(17)<br>E<br>Ir | 5 A CT + ACE<br>1 A CT + ACE | INr=k x N<br>N=CT turns .00578 ≤ K ≤ .26316 |

***See alternate CSH30 secondary connection in the Sepam Series 80 *Installation, Use, Commissioning and Maintenance* manual.**

*Note:* *INr should be thought of as a relay input port for ground fault protection. This port can accept residually connected phase ct's and therefore measure positive, negative and zero sequence components. This port can also accept a zero sequence ct which measures only true zero sequence (no positive or negative sequence). So the port name INr is just that a port name. What kind of current (positive, negative or zero sequence) depends on the type of CT's used)*

## Setting Coding

### Data Format

All the settings are transmitted in 32-bit signed 2's complement integer format.

### Coding of Tripping and Timer Hold Curves

The numbers correspond to the setting columns in the lists of settings.

① **Tripping Curves**
0 = definite time
1 = inverse9 = IEC VIT/B
2 = long time inverse10 = IEC EIT/C
3 = very inverse11 = IEEE Mod. inverse
4 = extremely inverse12 = IEEE very inverse
5 = ultra inverse13 = IEEE extr. inverse
6 = RI14 = IAC inverse
7 = IEC SIT/A15 = IAC very inverse
8 = IEC LTI/B16 = IAC extr. inverse
24 = Customized curve

② **Tripping Curves**

0 = definite11 = IEEE moderately inverse
7 = IEC inverse / A12 = IEEE very inverse
8 = IEC long time inverse / B13 = IEEE extremely inverse
9 = IEC very inverse / B17 = Specific Schneider curve
10 = IEC extremely inverse / C20 = $RI^2$

③ **Timer Hold Curves**

0 = definite time
1 = IDMT

### Common Protection Settings

All protection functions have the following settings at the head of the table.

| Setting | Data | Format/Unit |
|---|---|---|
| 1 | Latching | 0: no<br>1: yes |
| 2 | Program logic | see details |
| 3 | Activity | 0: Off<br>1: On |
| 4 | Measurement origin | 0: mainsee note<br>1: additional |

Details on program-logic field

| *Bit* | *31* | *30* | *....* | *4* | *3* | *2* | *1* | *0* |
|---|---|---|---|---|---|---|---|---|
| | | | | | | DES | AGR | CDC |

CDC= 1: the protection function takes part in circuit-breaker/contactor control
= 0: the protection function does not take part
AGR= 1: the protection function takes part in genset shutdown
= 0: the protection function does not take part
DES= 1: the protection function takes part in de-excitation
= 0: the protection function does not take part

When a common protection setting is not applicable to a particular protection function, it is signaled "reserved" in the table for the function.

***Nota :*** *there are a few special cases of coding for the measurement-origin field, listed below.*

| Value | 50N/51N | 67N | 59N |
|---|---|---|---|
| 0 | IrΣ | IrΣ | Vr |
| 1 | Ir | Ir | $V_{Ln}t$ |
| 2 | I’r | I’r | |
| 3 | I’rΣ | | |

## Protection Settings

They are organized according to **increasing ANSI codes**.

### ANSI 12 - Overspeed

Function number: 72xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Set point | % |
| 6 | Tripping time delay | 10 ms |

### ANSI 14 - Underspeed

Function number: 77xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Set point | % |
| 6 | Tripping time delay | 10 ms |

### ANSI 21B - Underimpedance

Function number: 7401

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Zs set point | mΩ |
| 6 | Tripping time delay | 10 ms |

### ANSI 24 - Overexcitation (V/Hz)

Function number: 75xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | VT connection | 0: delta<br>1: wye |
| 6 | Tripping curve | 0 = definite21 = Type A<br>22 = Type B23 = Type C |
| 7 | Voltage/frequency threshold | 0.01 pu |
| 8 | Tripping time delay | 10 ms |

### ANSI 27 - Undervoltage

Function number: 32xx
Unit 1: xx = 01 to unit 4: xx = 04

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Tripping curve | 0: definite<br>19: IDMT |
| 6 | Voltage mode | 0: phase-to-neutral<br>1: phase-to-phase |
| 7 | Threshold voltage | % $V_{LL}$p |
| 8 | Tripping time delay | 10 ms |

### ANSI 27D - Positive Sequence Undervoltage

Function number: 38xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Threshold voltage | % $V_{LL}$p |
| 6 | Tripping time delay | 10 ms |

### ANSI 27R - Remanent Undervoltage

Function number: 35xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Threshold voltage | % $V_{LL}$p |
| 6 | Tripping time delay | 10 ms |

## ANSI 32P - Directional Active Overpower

Function number: 53xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Access | 0: reverse power<br>1: overpower |
| 6 | Ps set point | 100 W |
| 7 | Tripping time delay | 10 ms |

## ANSI 32Q - Directional Reactive Overpower

Function number: 5401

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Access | 0: reverse power<br>1: overpower |
| 6 | Qs set point | 100 var |
| 7 | Tripping time delay | 10 ms |

## ANSI 37 - Phase Undercurrent

Function number: 2201

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Threshold current | 0.1 A |
| 6 | Tripping time delay | 10 ms |

## ANSI 37P - Directional Active Underpower

Function number: 55xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Access | 0: drawn<br>1: supplied |
| 6 | Ps set point | 100 W |
| 7 | Tripping time delay | 10 ms |

## ANSI 38/49T - Temperature Monitoring

Function number: 46xx
Unit 1: xx = 01 to unit 16: xx = 16

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Ts1 alarm set point | °C |
| 6 | Ts2 alarm set point | °C |

## ANSI 40 - Field Loss (Underimpedance)

Function number: 7001

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Xa resistance | 1 mΩ |
| 6 | Xb resistance | 1 mΩ |
| 7 | Xc resistance | 1 mΩ |
| 8 | Tripping time delay circle 1 | 10 ms |
| 9 | Tripping time delay circle Xd | 10 ms |

## ANSI 46 - Negative Sequence / Unbalance

Function number: 45xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Tripping curve | ② |
| 6 | Threshold current | % IB |
| 7 | Tripping time delay | 10 ms |
| 8 | K setting | 1 to 100 |

## ANSI 47 - Negative Sequence Overvoltage

Function number: 40xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Threshold voltage | % $V_{LL}$p |
| 6 | Tripping time delay | 10 ms |

## ANSI 48/51LR - Locked Rotor / Excessive Starting Time

Function number: 4401

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Threshold current | % IB |
| 6 | "ST" excessive starting time | 10 ms |
| 7 | "LT" locked rotor time | 10 ms |
| 8 | "LTS" locked on start time | 10 ms |

## ANSI 49RMS - Thermal Overload for Cables and Machines

Function number: 4301

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Negative sequence factor (K) | 0: none (0)1: low (2.25)<br>2: medium (4.5)3: high (9) |
| 6 | Is set point (shift group 1/group 2) | % IB |
| 7 | Ambient temperature taken into account | 0: no<br>1: yes |
| 8 | Maximum equipment temperature | °C |
| 9 | Additional settings taken into account (group 2) | 0: no<br>1: yes |
| 10 | Learnt cooling time constant (T2 learnt) taken into account | 0: no<br>1: yes |
| 11 | Group 1 - thermal alarm set point | % |
| 12 | Group 1 - thermal tripping set point | % |
| 13 | Group 1 - heating time constant | min. |
| 14 | Group 1 - cooling time constant | min. |
| 15 | Group 1 - initial heat rise | % |
| 16 | Group 2 - thermal alarm set point | % |
| 17 | Group 2 - thermal tripping set point | % |
| 18 | Group 2 - heating time constant | min. |
| 9 | Group 2 - cooling time constant | min. |
| 20 | Group 2 - initial heat rise | % |
| 21 | Group 2 - base current for group 2 | 0.1 A |
| 22 | Current threshold | 0.1 A |
| 23 | Associated time constant | min. |

***Nota :*** *parameters 1 to 21 concern the machine thermal overload, the common protection settings and parameters 22 and 23 concern the cable thermal overload.*

## ANSI 50/27 - Inadvertent Energization

Function number: 7301

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Is set point | 0.1 A |
| 6 | Vs set point | % $V_{LL}$p |
| 7 | T1 time | 10 ms |
| 8 | T2 time | 10 ms |
| 9 | Use of breaker-position inputs | 0: no<br>1: yes |

## ANSI 50BF - Breaker Failure

Function number: 9801

| Setting | Data | Format/Unit |
|---|---|---|
| 1 | Common settings | |
| 2 | Reserved | |
| 3 | Common settings | |
| 4 | Reserved | |
| 5 | Use of breaker closed input | 0: no<br>1: yes |
| 6 | Is set point | 0.1 A |
| 7 | Time | 10 ms |

## ANSI 50/51 - Phase Overcurrent

Function number: 01xx
Unit 1: xx = 01 to unit 8: xx = 08

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Confirmation | 0 = none<br>1 = neg. seq. overvoltage<br>2 = undervoltage |
| 6 | Group A - tripping curve | ① |
| 7 | Group A - Is threshold current | 0.1 A |
| 8 | Group A - tripping time delay | 10 ms |
| 9 | Group A - timer hold curve | ③ |
| 10 | Group A - timer hold | 10 ms |
| 11 | Group B - tripping curve | ① |
| 12 | Group B - Is threshold current | 0.1 A |
| 13 | Group B - tripping time delay | 10 ms |
| 14 | Group B - timer hold curve | ③ |
| 15 | Group B - timer hold | 10 ms |

## ANSI 50N/51N - Ground Fault

Function number: 06xx
Unit 1: xx = 01 to unit 8: xx = 08

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Group A - tripping curve | ① |
| 6 | Group A – Isr threshold current | 0.1 A |
| 7 | Group A - tripping time delay | 10 ms |
| 8 | Group A - timer hold curve | ③ |
| 9 | Group A - timer hold | 10 ms |
| 10 | Group A - H2 restraint | 0: yes<br>1: no |
| 11 | Group B - tripping curve | ① |
| 12 | Group B - threshold current | 0.1 A |
| 13 | Group B - tripping time delay | 10 ms |
| 14 | Group B - timer hold curve | ③ |
| 15 | Group B - timer hold | 10 ms |
| 16 | Group B - H2 restraint | 0: yes<br>1: no |

## ANSI 50V/51V - Voltage-Restrained Overcurrent

Function number: 19xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Tripping curve | ① |
| 6 | Threshold current | 0.1 A |
| 7 | Tripping time delay | 10 ms |
| 8 | Timer hold curve | ③ |
| 9 | Timer hold | 10 ms |

## ANSI 59 - Overvoltage

Function number: 28xx
Unit 1: xx = 01 to unit 4: xx = 04

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Voltage mode | 0: phase-to-neutral<br>1: phase-to-phase |
| 6 | Threshold voltage | % $V_{LL}p$ |
| 7 | Tripping time delay | 10 ms |

## ANSI 59N - Neutral Voltage Displacement

Function number: 39xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Tripping curve | 0: definite<br>19: IDMT |
| 6 | Threshold voltage | % $V_{LL}p$ |
| 7 | Tripping time delay | 10 ms |

## ANSI 27TN/64G2 - Third Harmonic Undervoltage

Function number: 71xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Access | 0: adaptive<br>1: fixed |
| 6 | Vs set point | 0.1% $V_{LL}$tp |
| 7 | Min. Ss set point | % Sb |
| 8 | Min. Vs set point | % $V_{LL}$p |
| 9 | K set point | 0.01 |
| 10 | Tripping time delay | 10 ms |

## ANSI 64 REF - Restricted Ground Fault Differential

Function number: 64xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Threshold current | 0.1 A |

## ANSI 66 - Starts per Hour

Function number: 4201

| Setting | Data | Format/Unit |
|---|---|---|
| 1 | Common settings | |
| 2 | Reserved | |
| 3 | Common settings | |
| 4 | Reserved | |
| 5 | Period of time | Hours |
| 6 | Total number of starts | 1 |
| 7 | Number of consecutive hot starts | 1 |
| 8 | Number of consecutive cold starts | 1 |
| 9 | Time delay between stop and start | min. |

## ANSI 67 - Directional Phase Overcurrent

Function number: 52xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Group A - direction | 0: line1: bus |
| 6 | Group A - characteristic angle | 3: 30°4: 45°5: 60° |
| 7 | Group A - tripping logic | 0: 1/31: 2/3 |
| 8 | Group A - tripping curve | ① |
| 9 | Group A - Is threshold current | 0.1 A |
| 10 | Group A - tripping time delay | 10 ms |
| 11 | Group A - timer hold curve | ③ |
| 12 | Group A - timer hold | 10 ms |
| 13 | Group B - direction | 0: line1: bus |
| 14 | Group B - characteristic angle | 3: 30°4: 45°5: 60° |
| 15 | Group B - tripping logic | 0: 1/31: 2/3 |
| 16 | Group B - tripping curve | ① |
| 17 | Group B - Is threshold current | 0.1 A |
| 18 | Group B - tripping time delay | 10 ms |
| 19 | Group B - timer hold curve | ③ |
| 20 | Group B - timer hold | 10 ms |

## ANSI 67N/67NC - Directional Ground Fault

Function number: 50xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Access | 0: projection<br>1: directional |
| 6 | Group A - direction | 0: line1: bus |
| 7 | Group A - characteristic angle | 0: -45°1: 0°2: 15°<br>3: 30°4: 45°5: 60°<br>6: 90° |
| 8 | Group A - sector | 2: sector 763: sector 83<br>4: sector 86 |
| 9 | Group A - tripping curve | ① |
| 10 | Group A – Isr threshold current | 0.1 A |
| 11 | Group A - tripping time delay | 10 ms |
| 12 | Group A – Vsr threshold current | % $V_{LL}$p |
| 13 | Group A - timer hold curve | ③ |
| 14 | Group A - timer hold | 10 ms |
| 15 | Group A - memory time | 10 ms |
| 16 | Group A - memory voltage | % $V_{LL}$p |
| 17 | Group B - direction | 0: line1: bus |
| 18 | Group B - angle | Same as group A |
| 19 | Group B - sector | Same as group A |
| 20 | Group B - tripping curve | ① |
| 21 | Group B - Isr threshold current | 0.1 A |
| 22 | Group B - tripping time delay | 10 ms |
| 23 | Group B - Vsr threshold current | % $V_{LL}$p |
| 24 | Group B - timer hold curve | ③ |
| 25 | Group B - timer hold | 10 ms |
| 26 | Group B - memory time | 10 ms |
| 27 | Group B - memory voltage | % $V_{LL}$p |

## ANSI 78PS - Pole Slip

Function number: 7601

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Access | 0: equal-area criterion<br>1: power-swing criterion<br>2: both criteria |
| 6 | T area | 10 ms |
| 7 | Max. number of power swings | 1 to 30 |
| 8 | Max. time between power swings | 10 ms |

## ANSI 81H - Overfrequency

Function number: 57xx
Unit 1: xx = 01 to unit 2: xx = 02

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Frequency threshold | 0.1 Hz |
| 6 | Tripping time delay | 10 ms |
| 7 | Reserved | |
| 8 | Vs set point | % $V_{LL}$p |

## ANSI 81L - Underfrequency

Function number: 56xx
Unit 1: xx = 01 to unit 4: xx = 04

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 4 | Common settings | |
| 5 | Frequency threshold | 0.1 Hz |
| 6 | Tripping time delay | 10 ms |
| 7 | Restraint | 0: no<br>1: yes |
| 8 | Vs set point | % $V_{LL}$p |
| 9 | BLOCK set point for frequency variation | Hz/s |

### ANSI 87M - Machine Differential

Function number: 6201

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Ids threshold current | 1 A |
| 6 | Restraint on CT loss | 0: no<br>1: yes |

### ANSI 87T - Transformer and Transformer-Machine Unit Differential

Function number: 6001

| Setting | Data | Format/Unit |
|---|---|---|
| 1 to 3 | Common settings | |
| 4 | Reserved | |
| 5 | Ids set point | % |
| 6 | Id/It set point | % |
| 7 | Restraint on CT loss | 0: no<br>1: yes |
| 8 | Test mode | 0: no<br>1: yes |

## Other Function Settings

### ANSI 60 - CT Supervision

Function number: 2601: CT supervision
2602: Supervision additional CTs

| Setting | Data | Format/Unit |
|---|---|---|
| 1 | Reserved | |
| 2 | Reserved | |
| 3 | Common settings | |
| 4 | Reserved | |
| 5 | Action on 21G, 46, 40, 51N, 32P, 37P, 32Q, 78PS and 64REF functions | 0: none<br>1: block |
| 6 | Tripping time delay | 10 ms |

### ANSI 60FL - VT Supervision

Function number: 2701: VT supervision
2702: reserved

| Setting | Data | Format/Unit |
|---|---|---|
| 1 | Reserved | |
| 2 | Reserved | |
| 3 | Common settings | |
| 4 | Reserved | |
| 5 | Use breaker-position or voltage-presence criterion | 1: circuit breaker<br>2: voltage |
| 6 | Check loss of 3 V/2 $V_{LL}$ | 0: no<br>1: yes |
| 7 | Test current | 0: no<br>1: yes |
| 8 | Use V2, I2 criterion | 0: no<br>1: yes |
| 9 | Action on 21G, 27/27S, 27D, 27TN, 32P, 32Q, 37P, 40, 47, 50/27, 51V, 59, 59N and 78PS functions | 0: none<br>1: block |
| 10 | Action on 67 function | 0: non directional<br>1: block |
| 11 | Action on 67N function | 0: non directional<br>1: block |
| 12 | V2 tripping set point | % |
| 13 | I2 tripping set point | % |
| 14 | 3 V/ 2 $V_{LL}$ loss time | 10 ms |
| 15 | V2, I2 criterion time | 10 ms |

### ANSI 79 - Recloser

Function number: 1701

| Setting | Data | Format/Unit |
|---|---|---|
| 1 | Reserved | |
| 2 | Reserved | |
| 3 | Common settings | |
| 4 | Reserved | |
| 5 | Number of shots | 0 to 4 |
| 6 | Reclaim time | 10 ms |
| 7 | Safety time until ready | 10 ms |
| 8 | Maximum additional dead time | 0: no<br>1: yes |
| 9 | Maximum wait time | 10 ms |
| 10 | Step 1 activation mode | see note |
| 11 | Step 2, 3, 4 activation mode | see note |
| 12 | Step 1 dead time | 10 ms |
| 13 | Step 2 dead time | 10 ms |
| 14 | Step 3 dead time | 10 ms |
| 15 | Step 4 dead time | 10 ms |

***Nota :** The activation of each of the cycles is coded as follows:*

| Bit | Activation by (if bit set to 1) / Non activation by (if bit set to 0) |
|---|---|
| 0 | Instantaneous protection 50/51 unit 1 |
| 1 | Delayed protection 50/51 unit 1 |
| 2 | Instantaneous protection 50/51 unit 2 |
| 3 | Delayed protection 50/51 unit 2 |
| 4 | Instantaneous protection 50/51 unit 3 |
| 5 | Delayed protection 50/51 unit 3 |
| 6 | Instantaneous protection 50/51 unit 4 |
| 7 | Delayed protection 50/51 unit 4 |
| 8 | Instantaneous protection 50N/51N unit 1 |
| 9 | Delayed protection 50N/51N unit 1 |
| 10 | Instantaneous protection 50N/51N unit 2 |
| 11 | Delayed protection 50N/51N unit 2 |
| 12 | Instantaneous protection 50N/51N unit 3 |
| 13 | Delayed protection 50N/51N unit 3 |
| 14 | Instantaneous protection 50N/51N unit 4 |
| 15 | Delayed protection 50N/51N unit 4 |
| 16 | Instantaneous protection 67N unit 1 |
| 17 | Delayed protection 67N unit 1 |
| 18 | Instantaneous protection 67N unit 2 |
| 19 | Delayed protection 67N unit 2 |
| 20 | Instantaneous protection 67 unit 1 |
| 21 | Delayed protection 67 unit 1 |
| 22 | Instantaneous protection 67 unit 2 |
| 23 | Delayed protection 67 unit 2 |
| 24 | Instantaneous V_DECL logical equation |

# Function Settings
## General &
## Application-Specific Parameters

## General Parameters

These settings are read accessible only.
Function number: D002

| Setting | Data | Format/Unit |
|---|---|---|
| 1 | Working language | 1: English 2: other |
| 2 | Rated frequency | 50, 60 (Hz) |
| 3 | Active group of settings | 1: group A 2: group B<br>3: selection by logic input<br>4: selection by remote control |
| 4 | Demand-value integration period | 5, 10, 15, 30, 60 minutes |
| 5 | Type of cubicle | 1: main 2: feeder |
| 6 | Active-energy increment | 100 to 5000000 (W) |
| 7 | Reactive-energy increment | 100 to 5000000 (var) |
| 8 | Phase-rotation direction | 1: direction 123 2: direction 132 |
| 9 | Temperature unit | 1: °C 2: °F |
| 10 | Remote-setting authorization | 1: no 2: yes |
| 11 | Time synchronization mode | 1: COM1 port 2: COM2 port<br>3: input I103 5: none |
| 12 | Remote-control mode | 1: SBO mode 2: direct mode |
| 13 | Reserved | |
| 14 | Monitoring of auxiliary power | 1: inactive 2: active |
| 15 | Rated auxiliary voltage | 24 to 250 (V DC) |
| 16 | Aux. voltage alarm low set point | % rated Vaux, min. 20 V |
| 17 | Aux. voltage alarm high set point | % rated Vaux, max. 275 V |
| 18 | Logic inputs ignored on loss of Vaux | 1: inactive 2: active |
| 19 | Base current IB | 0.2 to 1.3 IN (A) |
| 20 | Rated current IN | 1 to 6250 A |
| 21 | Number of phase CTs | 1: 2 CTs 2: 3 CTs |
| 22 | Phase CT rating | 1: 1 A 2: 5 A3: LPCT |
| 23 | Rated residual current INr | 10 to 62500 (dA) |
| 24 | Residual current measurement mode | 1: CSH 2 A 3: CSH 20 A<br>4: CSH + CT 1 A 6: CSH + CT 5 A<br>8: ACE990 range 1<br>9: ACE990 range 2<br>11: not measured |
| 25 | Reserved | |
| 26 | Rated primary voltage $V_{LL}p$ | 220 to 250000 (V) |
| 27 | Rated secondary voltage $V_{LL}s$ | 100, 110, 115, 120, 200, 230 (V) |
| 28 | VT wiring | 1: 3 $V_{Ln}$, 2: 2 $V_{LL}$, 3: 1 $V_{LL}$, 4: 1 $V_{Ln}$ |
| 29 | Residual voltage mode | 1: none 2: $\Sigma 3V$<br>3: VT $V_{LL}s/\sqrt{3}$ 4: VT $V_{LL}s/3$ |
| 30 | Neutral-point residual voltage measurement | 1: none 2: present |
| 31 | Neutral-point rated voltage $V_{LL}p$ | 220 to 250000 (V) |
| 32 | Neutral-point rated voltage $V_{LL}s$ | 57 V to 133 V |
| 33 | Reserved | |
| 34 | Reserved | |
| 35 | Additional rated current I'n | 1 to 6250 A |
| 36 | Number of additional phase CTs | 1: 2 CTs 2: 3 CTs3: none |
| 37 | Additional phase CT rating | 1: 1 A 2: 5 A3: LPCT |
| 38 | Additional rated residual current I'Nr | 10 to 62500 (dA) |
| 39 | Additional residual current measurement mode | Idem 24 |
| 40 | Reserved | |
| 41 | Reserved | |
| 42 | Reserved | |
| 43 | Reserved | |
| 44 | Reserved | |
| 45 | Reserved | |
| 46 | Reserved | |
| 47 | Reserved | |
| 48 | Reserved | |

## Application-Specific Parameters

These settings are read accessible only.
Function number: D003

| Setting | Data | Format/Unit |
|---|---|---|
| 1 | Transformer presence | 1: no 2: yes |
| 2 | Voltage winding 1 $V_{LL}1$ | 220 to 250000 V |
| 3 | Voltage winding 2 $V_{LL}2$ | 220 to 440000 V |
| 4 | Power S | 100 to 999000 kVA |
| 5 | Vector shift | 0 to 11 |
| 6 | Rated motor speed | 100 to 3600 rpm |
| 7 | Number of pulses per rotation | 1 to 1800 |
| 8 | Zero speed threshold | 5 to 20% |

**Schneider Electric USA**
295 Tech Park Drive, Suite 100
LaVergne, TN 37086
Tel : 1-888-SquareD (1-888-778-2733)
www.us.squared.com

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